Province of British Columbia
Ministry of Environment

Studies on
Aquatic Macrophytes
Part XXVIII

Considerations for Use of the AQUA-KLEEN Formulation of 2,4-D for Control of Eurasian Water Milfoil in British Columbia

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April, 1983
File No.: 64.1009

ABSTRACT

Observations on the effectiveness, persistence and drift of 2,4-D (Aqua-Kleen) were reviewed following 33 treatments to control Eurasian water milfoil between 1976 and 1981. These experiments indicated that in certain locations, 2,4-D was effective in removing nuisance weed growth for up to three years following treatments. Legal considerations, procedures for application and monitoring, and technical information on 2,4-D and other treatment methods were reviewed to guide implementation of future treatment programs. The major advantage of herbicide use was that in some sites it could be applied relatively quickly, over large areas, at a low cost. The major limitation of herbicide treatments was possible conflicts with water use. Following experimental treatments, concentrations of 2,4-D above the drinking water standard (0.1 mg/L) persisted in the treated area for a maximum of 4 to 6 days. Drift at this concentration was detected at a maximum of 125 m from open water treatments of 12 ha or less in large lakes. Low concentrations of herbicide (just above 0.001 mg/L) were observed to drift up to 2 km and, typically, persisted for less than 40 days in treatment areas. It was unlikely that well water near treatment areas could be contaminated with 2,4-D, but the potential for hydraulic continuity between wells and treated water should be considered. No significant detrimental effects on non-target organisms were observed, although agencies responsible for wildlife resources should be contacted about new treatment sites.

ACKNOWLEDGEMENTS

Mr. Ian McDougall compiled report sections on legal considerations and the role of Ministry of Environment agencies. Mr. Cliff Dyer assisted with the analysis of data and drafting of sections on technical considerations, application of herbicide and monitoring considerations.

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1. INTRODUCTION

It is only recently that aquatic herbicides have been tested and used for aquatic weed control in British Columbia. Procedures and considerations for the use of aquatic herbicides have not been fully documented. It is recognized however, that particular caution must be observed in the application of pesticides to aquatic systems since there may be potential for widespread distribution of the material applied, and for conflicts with multiple water use including recreation, water supply for domestic, industrial or irrigation purposes and habitat for fish and waterfowl.

Commencing in 1976, staff of the Water Management Branch of the B.C. Ministry of Environment conducted field tests and collected information on the use of the butoxyethanol ester (BEE) formulation of 2,4-D (marketed under the name Aqua-Kleen) for control of the nuisance aquatic plant, Eurasian water milfoil (known scientifically as Myriophyllum spicatum L.). Observations were made on efficacy, persistence and drift of the herbicide, and the effects of different 2,4-D application rates on non-target organisms in a variety of sites. Logistics of implementing full scale treatments were also evaluated. These experiments indicated that in certain locations, 2,4-D BEE may be useful for control of Eurasian water milfoil.

The results of the experimental observations made by Water Management Branch staff have been documented in technical reports (Adams and Wallis, in prep.; Anon., 1979, 1980a, 1980b, 1980c; Goddard, 1980; Lim, 1978; Lim and Lozoway, 1977; Rudolph and Dyer, 1981). These results are summarized here along with other pertinent information to provide guidelines for the use of the Aqua-Kleen formulation of 2,4-D BEE for the control of Eurasian water milfoil. This information was compiled to provide assistance to agencies and individuals considering use of 2,4-D for Eurasian water milfoil control and to provide direction in making applications for herbicide use permits.

2. LEGAL CONSIDERATIONS

2.1 FEDERAL LEGISLATION

In accordance with the Pest Control Products Act, all herbicides must be registered with Agriculture Canada before they can be sold or used in Canada. A Pest Control Products Registration Number must appear on every product label (see Appendix I).

Other federal statutes which apply to the controlled use of herbicides include: the Food and Drugs Act, the Fisheries Act, and the Migratory Bird Regulations.

2.2 PROVINCIAL LEGISLATION

The sale, distribution, transportation, storage and application of aquatic herbicides is regulated by the British Columbia Pesticide Control Act and the Pesticide Control Act Regulation. The Pesticide Control Branch, B.C. Ministry of Environment, is responsible for administering the Pesticide Control Act.

2.3 PROVINCIAL PEST CONTROL SERVICE LICENCE

A Pest Control Service Licence must be obtained for each office or place of business from which a service involving the use or application of pesticide is sold or provided. (For further details on requirements for obtaining a Pest Control Service Licence, see the Pesticide Control Branch publication: Handbook For Pesticide Applicators and Pesticide Dispensers, B.C. Ministry of Environment).

2.4 APPLICATOR'S CERTIFICATION

Pesticide applicators must be certified through examination by the Pesticide Control Branch.

A certified pesticide applicator possessing a valid Applicator's Certificate for Aquatic Weed Control must be in attendance at any aquatic herbicide application. Each application of aquatic herbicide must be recorded on a Pest Control Operation Record at the time of application.

Certified pesticide applicators are responsible for the safe handling, loading, transportation, application and storage of any aquatic herbicide.

2.5 PERMIT PROCEDURES

All permit requests for proposed aquatic herbicide applications are reviewed by the British Columbia Pesticide Control Committee under the permit granting procedure. Committee members represent both federal and provincial agencies including Environment Canada as well as the B.C. Ministries of Agriculture and Food, Environment (Water Management Branch, Fish and Wildlife Branch, Pesticide Control Branch), Forests and Health.

A permit must be obtained for aquatic herbicide application in any body of water unless it is a man-made, self-contained body on private land. Temporary diking of a body of water normally contiguous with a natural water system is not sufficient to exempt it from permit requirements.

Applications for pesticide use permits should be submitted on approved forms to the Pesticide Control Branch, 810 Blanshard Street, Victoria, B.C., V8W 3E1, at least four months prior to the proposed commencement date of pesticide use. Each submission must include seven copies of the application and maps.

Multiple year permits may be obtained where treatment in successive years can be anticipated in advance.

In order for a pesticide use permit request to be properly assessed by the Pesticide Control Branch, some details about the proposed treatment must be included on the application form. These include: Pest Control Service

Licence Number; purpose of treatment (and ideally, why other treatment methods are not appropriate); identification of target species; proposed herbicide and amount to be used; specific location and area of treatment, including a map; proposed method of application; review of treatment conflicts with other water use and resources; and identification of project supervisor and certified pesticide applicator.

An example of a pesticide use permit application[1] is provided in Appendix II.

2.6 PERMIT REQUIREMENTS

The Pesticide Control Branch, in consultation with the British Columbia Pesticide Control Committee, may issue a permit for the application of an aquatic herbicide subject to stipulated permit requirements. Such permit requirements will include some or all of the following:

a) Applicator certification is required in the aquatic weed category.
b) Applicator's place of business must possess a valid Pest Control Service Licence.
c) Project supervision is required.
d) Rate of herbicide application must not exceed a specified maximum level as stipulated on the herbicide label.
e) Specified application equipment must be used.
f) Treatments are restricted to areas with specified levels of nuisance target species.
g) Treatment area is limited to a specified maximum size.
h) No domestic or irrigation water intakes are allowed to operate within a specified distance of the application. Users of such water intakes must be notified of herbicide treatment and be provided with alternate water until 2,4-D residues are below specified concentrations. Monitoring of 2,4-D residues and reporting of results to Pesticide Control Branch may be required.

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1 Format of this form is currently under revision.

i) Access roads and shorelines must be posted for a specified time period to inform the public of treatment and to discourage use of treated water.

j) The public must be notified when to resume water use.

k) Purpose and scope of the project must be published in specified newspapers near the proposed application site.

l) Copies of permits and treatment area maps must be posted in specified office locations or public access areas.

m) Special instructions may be included regarding environmentally sensitive treatment locations.

n) Special exemptions may be given regarding environmentally insensitive treatment locations.

o) Permit conditions must be communicated to all project personnel.

p) The nearest Pesticide Control Branch office must be notified prior to commencement of project.

Other requirements may be stipulated in the pesticide use permit.

2.7 RESPONSIBILITIES OF PERMITTEE

All aquatic herbicides must be applied in accordance with the terms of the permit. A permittee who fails to comply with the terms of the permit is subject to conviction and may be liable to a fine of not more than $2000, or imprisonment for six months, or to both, and is subject to additional fines, or imprisonment, for any subsequent similar offence (see Pesticide Control Act and Regulation).

2.8 APPEAL PROCEDURES

Any appeal of a specific herbicide permit must be sent by registered mail to the Chairman, Environmental Appeal Board, Parliament Buildings, Victoria, B.C., V8V 1X5 (or left for him during business hours at the address of the Board, Room 218, 557 Superior St., Victoria, B.C.).

An appeal must be filed within 15 days following the effective date specified in the permit.

The procedures on the appeal shall be those set out in the Environmental Appeal Board Procedure Regulation.

The notice of appeal shall contain the name and address of the appellant; the name of counsel or agent, if any, for the appellant; the address for service upon the appellant; grounds for appeal; particulars relative to the appeal; and a statement of the nature of the appeal order requested.

In some cases, a permit holder may wish to appeal the permit he or she has obtained if the requirements stipulated in the permit are not satisfactory.

The notice of appeal shall be signed by the appellant, or on his behalf by his counsel or agent, and the notice of appeal for each action, decision or order appealed shall be accompanied by the fee specified, made payable to the Minister of Finance.

The Chairman of the Environmental Appeal Board will not be obliged to proceed with an appeal which is deficient in some manner prescribed by the Environmental Appeal Board Procedure Regulation. The Chairman will request that the appellant makes appropriate corrections before the appeal can proceed.

The Chairman of the Environmental Appeal Board shall immediately acknowledge receipt of any appeal which satisfactorily meets the requirements of the Environmental Appeal Board Procedure Regulation. Copies of the notice of appeal and the letter of acknowledgement will be sent to the appellant, the Minister of Environment, the Administrator of the Pesticide Control Act and the permit holder (if other than the appellant). If the Chairman decides it is necessary that the Appeal Board hear the appeal, he will then set a date, time and location of the hearing which will be at least six, but not more than twelve weeks after delivery of the acknowledgement of the appeal. The appellant will then have at least six weeks to prepare for the appeal hearing.

If a permit is successfully appealed, it will be revoked, or appropriate modifications will be made to amend the permit.

2.9 PROCEDURES FOR OBTAINING ALTERNATE WATER SUPPLIES

It will usually be necessary to discontinue use of any water intakes within a herbicide treatment area or designated buffer zone for a specified time, or until herbicide concentrations in the water column are below a specified concentration. In addition, it may be required to discontinue use of any wells situated within a designated distance from the lakeshore adjacent to a treatment area for a specified time, or until herbicide concentrations in the water or lake bottom sediments are below specified concentrations.

Any alternate water supply acquired from a neighbouring irrigation district or other water utility (which obtains water from another water body or system) must be approved by the Comptroller of Water Rights, Water Management Branch, B.C. Ministry of Environment.

Any alternate water supply acquired from a municipality should be authorized by the appropriate municipal government responsible for the service.

Alternate water supplies which are obtained from sources other than through local community systems should be approved by the local Medical Health Officer.

3. THE ROLE OF MINISTRY OF ENVIRONMENT AGENCIES

3.1 PESTICIDE CONTROL BRANCH

The Pesticide Control Branch of the Ministry of Environment has the statutory responsibility (Pesticide Control Act) of ensuring that pesticides are sold, used, stored, disposed of and otherwise handled in a manner that will pose no undue risk to human health or environmental quality.

The primary functions of the Pesticide Control Branch are:

a) to review applications and issue permits for pesticide use in consultation with the British Columbia Pesticide Control Committee,
b) to certify and license pesticide applicators, and
c) to monitor compliance with the Pesticide Control Act, Regulations and Pesticide Use Permits.

Staff of the Pesticide Control Branch may conduct inspections and investigations and the Administrator may revoke or suspend a licence, permit or certificate for reasons of violations or environmental safety.

3.2 WATER MANAGEMENT BRANCH

Staff of the Water Management Branch review scientific and technical literature to develop knowledge and expertise on aquatic plant management techniques. The use of aquatic herbicides as a control method is included in these reviews.

Staff of the Water Management Branch are authorized to provide requesting agencies or individuals with advice on the use of aquatic herbicides for aquatic plant management. Information is available to any requesting agency or individual concerning herbicide use and effectiveness, application methods, environmental considerations and non-chemical alternatives for aquatic plant control.

At the request of the Pesticide Control Branch, staff of the Water Management Branch are authorized to provide requesting agencies or individuals with assistance in completing applications for pesticide use permits. Assistance may include providing the applicant with technical information or advice relating to recommended herbicide use, treatment design, precautionary measures, application techniques and monitoring procedures.

The Water Management Branch serves only as an advisory agency to applicants for pesticide use permits and is not responsible for the final decision on applications for permits made to the Pesticide Control Branch.

In general, the Water Management Branch will not apply for pesticide use permits, on its own initiative, to control common nuisance aquatic plants in British Columbia. However, the Branch may apply for permits where a herbicide treatment will control an introduced nuisance species and protect the Province from further spread, or to evaluate newly registered aquatic herbicides, or to conduct experimental field trials.

The Water Management Branch may act as the certified applicator or lend herbicide application equipment or perform basic monitoring in shared-cost treatments initiated by other Ministries or local authorities.

In non-shared-cost treatments, the Water Management Branch may provide requesting agencies with herbicide application equipment, on a loan basis, for use by other certified applicators.

4. TECHNICAL CONSIDERATIONS

4.1 INTRODUCTION

From 1976 to 1981, 33 Aqua-Kleen applications to control Eurasian water milfoil were monitored by staff of the Water Management Branch. Treatment sizes ranged from a 0.9 m^2 lab test, to spot applications up to 0.4 ha (in an attempt to kill small clumps of plants just becoming established), to block treatments up to 12 ha. SCUBA divers observed the condition of plants within and adjacent to treated areas from several months before to several years following herbicide treatments. Over 5,000 water samples were taken in treatment areas to observe the persistence of 2,4-D in the water column and at various distances outside treatment areas to observe herbicide drift. A special study was made of the potential for 2,4-D to move in groundwater and the B.C. Fish and Wildlife Branch studied the effect of 2,4-D on non-target organisms, including fish, waterfowl and invertebrates.

Results of testing the herbicide 2,4-D indicate it is appropriate as one tool among several for aquatic plant management in specific situations; its suitability depends on such factors as site-specific costs and potential effectiveness. The main advantage of 2,4-D over other control methods is that it can eliminate nuisance growth for 2 to 3 years in some sites. This compares very favorably with harvesting, for example, which is required twice per year in some Okanagan Valley lake sites. The major limitation of herbicide use is possible conflicts with water use, since if alternate water must be supplied to lake water users until the herbicide has dissipated, costs of treatment and monitoring may increase significantly. Evaluation of the herbicide 2,4-D for a specific use requires review of a number of technical considerations on timing of application, physical characteristics of the area to be treated, and the implications of treatment size to drift and persistence of herbicide.

4.2 IDENTIFICATION OF TARGET SPECIES

Eurasian water milfoil, known scientifically as Myriophyllum spicatum L., is an aquatic plant recently introduced to British Columbia and first noted as a nuisance in the early 1970's in Okanagan Lake. In lakes which have been previously free of M. spicatum, suspected new populations may be difficult to distinguish from at least two native Myriophyllum species found in British Columbia, M. exalbescens Fern., and M. verticillatum L. Therefore, expert advice on the identification of suspected M. spicatum populations is recommended. Positive identification may require chemical analysis[1].

The reaction of aquatic plants to the herbicide 2,4-D[2] is relatively species-specific and only some species are highly susceptible to low concentrations. M. spicatum is particularly sensitive and treatment with recommended dosages of Aqua-Kleen may effectively control M. spicatum by killing stems and roots without harming other aquatic plants. This herbicide should not be used to control unidentified species of nuisance growth or species about which 2,4-D susceptibility is unknown.

Mapping and documentation of specific areas inhabited by M. spicatum populations is desirable to ensure that herbicide is used judiciously and effectively. Although it is desirable to keep the amount of herbicide used to a minimum, all plants of the target species within the treatment area should be located and treated to prevent reinfestation and spread. Ideally, all target plants in a small lake, or all plants of an isolated population in a large lake should be treated to reduce the rate of reinfestation. Identification and mapping of the target plants requires trained personnel who can distinguish M. spicatum from above the water surface when water is

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1 The Water Management Branch maintains a staff knowledgeable about the identification of aquatic plants. A chemotaxonomic method of identification has been developed by Ceska (1977).

2 Only the butoxyethanol ester formulation of 2,4-D (Aqua-Kleen) is registered for aquatic use in Canada.

calm and clear, or by using diving gear when conditions warrant closer observations.

4.3 2,4-D EFFECTIVENESS FOR CONTROL OF EURASIAN WATER MILFOIL

Considerable variation was observed in the effectiveness of the 33 2,4-D treatments monitored between 1976 and 1981. In most sites, 2,4-D treatment at recommended application rates removed nuisance Eurasian water milfoil for the remainder of the treatment growing season and one subsequent growing season. The herbicide was most effective in enclosed water bodies. Westside Cays in Okanagan Lake, for example, was treated at rates of 10-33 kg a.i./ha and no treated Eurasian water milfoil was seen to survive. Walshe's Pond adjacent to Kalamalka Lake was treated at 22 kg a.i./ha in 1979 and only showed regrowth of sparse populations by the fall of 1981. Quantitative sampling of open water treatment sites in 1977 and 1978 indicated a reduction in stem density from 54 to 100 percent at the end of the treatment summer and elimination of nuisance densities for one or more subsequent summers, depending on the rate of reinfestation from adjacent, untreated populations, and the rate of regrowth from root crowns which survived the treatment.

In some of the small open water treatment plots (<0.5 ha), or plots treated at the low application rate, rapid regrowth occurred the year following treatment. In three larger treatments (2.0, 4.0 and 5.3 ha), at the high application rate, stem densities were still 70 to 90 percent less than surrounding untreated densities two years after treatments.

Treatment conditions that may result in variable plant mortality include the following:

(a) Application Rate

Recommended application rates specified for the Aqua-Kleen formulation of 2,4-D are 22 kg a.i./ha for light to moderate infestations or 45 kg

a.i./ha for dense infestations, where the water is more than 2.4 m deep and where there is a large volume turnover (water movement). Observation of treatments in the Okanagan lakes system indicated that the low application rate resulted in more rapid regrowth than the higher application rate in open lake sites. Thus the 44 kg a.i./ha rate is recommended for large lakes where the herbicide can be quickly diluted. Dissipation of the herbicide was enhanced by wind-induced currents, groundwater discharge and creek inflow. It also was observed that herbicide applied to small areas and/or long narrow areas was subject to rapid dissipation and was less effective than large block applications. In enclosed water bodies where nearly all the surface area was treated (ponds, lagoons) the lower application rate (22 kg a.i./ha) was adequate to achieve long term control.

(b) Density

It would appear that root contact and absorption of 2,4-D is essential to cause plant mortality. In dense weed beds, Aqua-Kleen pellets tend to become trapped and suspended in the foliage, thereby reducing the amount of herbicide reaching the substrate and root region of the plant. After some treatments, plants in the center of dense clumps survived, presumably because few herbicide pellets dropped through the dense foliage to release 2,4-D near the root system. To avoid this situation, it is recommended that treatments be carried out before dense surface mat formation in early summer or when the canopy has opened up in late summer. Also, herbicide applications may be integrated with mechanical harvesting to reduce the dense surface mat prior to granular herbicide application.

(c) Substrate Type

2,4-D treatment of Eurasian water milfoil growing on rocky bottoms in exposed Okanagan Lake locations resulted in relatively low plant mortality. This supports the hypothesis that 2,4-D release and persistence near roots is important for plant mortality. Finely divided sediments appear to retain larger quantities of 2,4-D than coarse substrates. On rocky bottoms, where roots penetrate crevices, the herbicide granules may have less contact with roots.

4.4 HERBICIDE PERSISTENCE IN THE TREATMENT AREA WATER COLUMN

It has been shown in laboratory experiments (Bothwell and Daley, 1981) that Aqua-Kleen granules release the active herbicidal ingredient most rapidly within the first day after application, then more slowly over several subsequent days. The herbicide is released as the butoxyethanol ester (BEE) form of 2,4-D which is quickly hydrolysed to 2,4-D acid at high pH and temperatures. The acid is dispersed in the water column, usually over a period of several days, and degradation occurs by various processes over several weeks or months.

Data collected by Water Management Branch staff on the persistence of 2,4-D in treated areas are summarized in Table 1. Herbicide concentrations were generally measured as 2,4-D acid.

The maximum concentration of 2,4-D acid sampled in open water treatment areas was 0.42 mg/L in surface water and 3.25 mg/L in bottom water. Maximum 2,4-D concentrations exceeded 0.1 mg/L in samples taken within about only 40 percent of the open water treatment sites, and rapidly declined to less than 0.1 mg/L 1-7 days following these treatments. In about 50 percent of the treatment sites, concentrations did not exceed 0.05 mg/L. Generally, 2,4-D acid concentrations declined to less than 0.01 mg/L within 15 days although there were exceptions where infrequent samples contained concentrations just above 0.01 mg/L for up to 45 days after treatment.

Maximum concentrations documented in the water column following treatments were low with respect to levels reported to kill Eurasian water milfoil. Elliston and Steward (1972) found that concentrations of 2,4-D BEE at 1 mg/L were required for 48 hours (at temperatures of 18°C) to kill Eurasian water milfoil. In comparison, Hall (1983) found that the minimum length of time required to produce 50 percent injury to Eurasian water milfoil with a continuous exposure to 0.03 to 0.05 mg/L 2,4-D acid was 3.5 weeks and 1 week with 0.1 mg/L 2,4-D. One hundred percent injury occurred after 11 weeks exposure to 0.1 mg/L. Concentrations theoretically required

TABLE 1

PERSISTENCE OF 2,4-D ACID IN TREATMENT AREAS FOLLOWING HERBICIDE APPLICATIONS, 1976-1981

A. Treatments smaller than 1 ha in open water, listed by treatment date

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Stations & (No. Samples)	Maximum[2] 2,4-D Conc.	Persistence in Days[3] per Conc. in mg/L > 0.1	>0.05	>0.01	>0.005	>0.001	Comments
N. Arm Okanagan Lake	31/5/76	0.60	22	3 (17)	0.140	2	2	3-8	3-8	3-8	Treatments separated by 50 m
	31/5/76	0.60	22	3 (17)	0.050	ND	<1	<1	2	3-8	
N. Arm Okanagan Lake	12/7/77	0.67	22	2 (69)	0.360	5	5	9	9	9	
	12/7/77	0.36	22/45	2 (73)	3.250	2	2	3	5	5	Treatments about 400 m apart
	12/7/77	0.30	33	2 (68)	0.670	2	2	8	8	8	
Lisheen Estates, Kalamalka Lake	17/7/78	0.07	22	3 (42)	0.013	ND	ND	1	1	10	Narrow band of weeds treated along 120 m shoreline; first sampled 1 day after treatment
Wilson's Landing, Okanagan Lake	01/8/78	0.10	45	3 (36)	0.011	ND	ND	1	3-7	3-7	First sampled 1 day after treatment
S. End Wood Lake	21/6/79	0.50	45	1 (7)	ND	-	-	-	-	-	First sampled 3 days after treatment; suspect last station affected by drift from 5.9 ha treatment 450 m to south on 9/6/79
	21/6/79	0.10	45	1 (7)	ND	-	-	-	-	-	
	21/6/79	0.10	45	1 (14)	0.012	ND	ND	8-11	11	18	
N. End Kalamalka Lake	21/6/79	0.21	22	1 (18)	0.020	ND	ND	8-11	18	18	First sampled 3 days after treatment; suspect stations affected by drift from 12 ha treatment 80 m away on 4/6/79
	21/6/79	0.21	45	1 (19)	0.029	ND	ND	6	8	18	
Cosens Bay, Kalamalka Lake	11/7/79	0.4 (2 sites)	45	2 (92)	0.030	ND	ND	8-13[4]	43-45	43-45	sites 100 m apart; first sampled 5 days after treatment
	01/8/79	0.2 (2 sites)	45	2 (40)	0.006	ND	ND	ND	15-19	28	sites 25 m apart; first sampled 12 days after treatment
	12/9/79	0.2 (3 sites)	45	3 (30)	0.007	ND	ND	ND	8-12	12	sites 300 m apart; first sampled 7 days after treatment
Cosens Bay, Kalamalka Lake	26/6/80	0.5 (6 sites)	45	4 (190)	0.023	ND	ND	4-6[5]	17	32	6 sites along 1500 m shoreline
Coldstream Ck., Kalamalka Lake	09/9/80	1.0 (2 sites)	45	2 (36)	0.035	ND	ND	5	7	>13[6]	sites 150 m apart

TABLE 1 (Continued)

A. Treatments smaller than 1 ha in open water (Continued)

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Stations & (No. Samples)	Maximum[2] 2,4-D Conc.	Persistence in Days[3] per Conc. in mg/L					Comments
						>0.1	>0.05	>0.01	>0.005	>0.001	
Lisheen Estates, Kalamalka Lake	30/7/80	0.2 (4 sites)	45	4 (55)	0.016	ND	ND	<1	1	14	4 sites along 1100 m shoreline
S. End Kalamalka Lake	25/9/80	1.52 (6 sites)	45	3 (42)	0.31	4-7	11-14	14-21	14-21	25-28	6 sites along 3.6 km shoreline; first sampled 4 days after treatment; suspect stations affected by drift from 8.5 ha treatment at N. end Wood Lake on 27/9/80

B. Treatments larger than 1 ha in open water, listed by treatment size

N. Arm Okanagan Lake	18/9/78	2.0	45	3 (80)	0.194	4-7	4-7	9-14	17-22	17-22	
N. end Skaha Lake	23/6/77	2.4	22/45	6 (97)	0.140	1	3	4	4	5	
Naswhito Ck., Okanagan Lake	27/6/77	3.1	45	6 (156)	0.233	4	6	6	6	8	
Summerland, Okanagan Lake	14/8/78	4.0	45	3 (73)	0.197	<1	<1	11-14	15	17	
Kelowna, Okanagan Lake	22/6/78	5.3	45	3 (39)	0.169	1	1	3	10-14	10-14	First sampled 1 day after treatment
S. End Wood Lake	08/6/79	5.9	22/45	4 (65)	0.027	ND	ND	21-24	41-46[7]	107	First sampled 9 days after treatment
N. End Kalamalka Lake	14/6/79	11.5	22/45	3 (72)	0.038	ND	ND	20	25	25	First sampled 5 days after treatment

TABLE 1 (Continued)

C. Treatments in enclosed water bodies, listed by treatment date

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Stations & (No. Samples)	Maximum[2] 2,4-D Conc.	Persistence in Days[1] per Conc. in mg/L					Comments
						> 0.1	>0.05	>0.01	>0.005	>0.001	
Laboratory Experiment	18/3/76	0.9 m^2	22	3 (144)	0.32	84-166	84-166	84-166	84-166	84-166	In this laboratory experiment, 2,4-D was applied to Myriophyllum spicatum growing in a Plexiglas cylinder measuring 2.1 m high by 1.1 m in diameter
Westside Cays, Okanagan Lake	12/7/77	2.4	11/22/33	4 (199)	4.00	43-59	43-59	43-59	43-59	43-59	All but one sample was below 0.1 mg/L on day 43; all samples <0.001 mg/L on day 59 as a result of Cays opened to mixing with Okanagan Lake on day 45
Walshe's Pond, Kalamalka Lake	01/8/79	0.20	22	1 (9)	1.22	61-77	61-77	>77	>77	>77	First sampled 12 days after treatment
S. End Wood Lake	10/9/80	10.0	45	4 (116)	0.62	1-4	1-4	43-47	47-50	50 -55	Conc. increased after 27/9/80 treatment at N. End Wood Lake; conc. in both areas was not detectable after fall turnover of lake water column.
N. End Wood Lake	27/9/80	8.5	45	4 (45)	0.015	ND	ND	26-30	30-33	30-38	First sampled 5 days after treatment.
Champion Lake	11/9/81	0.56 (4 sites)	45	2 (32)	0.288	<1	<1	45-268	45-268	45-268	Not sampled after day 45 until 21/6/82 when no herbicide was detected (<0.001).

TABLE 1 (Continued)

C. Treatments in enclosed water bodies, listed by treatment date (Continued)

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Stations & (No. Samples)	Maximum[1] 2,4-D Conc.	Persistence in Days[2] per Conc. in mg/L > 0.1	>0.05	>0.01	>0.005	>0.001	Comments
Solana Bay, Osoyoos Lake	16/9/81	6.14	44	2 (17)	2.06	49-190	>190	>190	>190	>190	Solana Bay was closed off from Osoyoos Lake by an earth barrier prior to treatment. Herbicide conc. declined over winter and were below 0.1 mg/L on 25/3/82; Bay was opened to Osoyoos Lake in May, 1982, and sampling in June showed no 2,4-D residues.

ND = not detected at this concentration

[1] Where several adjacent sites were treated, total area of all sites combined is given.

[2] Treatment areas were first sampled on treatment day (approx. 6 hrs. after treatment) and 1 day after treatment unless noted otherwise in comments. Maximum 2,4-D conc. are not comparable for sites first sampled 2 days or more after treatment as the highest conc. often occurred on the first day following treatment.

[3] Persistence is given as the last day when herbicide in water samples at any station was greater than specified concentrations. All samples taken on the next day were below the specified concentrations. Persistence is shown as a range where time between sample dates > 1 day.

[4] A sample with 2,4-D conc. of 0.012 mg/L collected on day 29 at Cosens Bay site 11/7/79 was anomalous.

[5] A sample with 2,4-D conc. of 0.016 mg/L collected on day 17 at Cosens Bay site 26/6/80 was anomalous.

[6] 2,4-D may have persisted a few days longer at concentrations <0.005 mg/L as no samples were taken after day 13 following the 9/9/80 Coldstream Ck. treatment

[7] A sample with 2,4-D conc. of 0.007 mg/L collected on day 96 at the S. end Wood Lake site 8/6/79 was anomalous.

to kill Eurasian water milfoil were generally not achieved in the water column at Okanagan Valley open water treatment sites. It was concluded that concentrations in the water column were not as important as the high concentrations measured in sediments to achieve the plant mortality observed following these treatments.

The decline to minimum detectable levels of 0.001 mg/L in open water treatments was rarely longer than 40 days. Persistence of low herbicide concentrations was not related to treatment size; for example, residues from spot treatments (<1 ha) could remain detectable for over 30 days but residues from a 5.3 ha treatment were not detectable after 15 days. Persistence was prolonged if there was little water movement (i.e. no wind or river-generated currents) to disperse the herbicide. In an extreme example of this situation, the water column remained at barely detectable levels (0.001-0.003 mg/L) for about 100 days in a corner of Wood Lake where water movement was restricted following treatment of 5.9 ha in 1979.

In enclosed treatment sites, concentrations as high as 2.06 mg/L were obtained in surface samples and 4.00 mg/L in bottom samples. In three enclosed areas where nearly the entire surface area was treated (Westside Cays, Walshe's Pond and Solana Bay) 2,4-D concentrations remained close to 1.0 mg/L or above for one to seven weeks which is well above the critical concentrations required to kill Eurasian water milfoil (Elliston and Steward, 1972). The high degree of control achieved in these locations confirmed that the critical concentrations had been exceeded.

Residues in enclosed sites generally declined more slowly than in open water sites, taking over 190 days to decline to non detectable levels following one treatment. Such enclosed sites included those where sufficient area was treated to produce detectable concentrations in the entire water column of a lake or pond, or in an isolated arm or semi-enclosed bay of a large lake. The herbicide persistence data from enclosed sites indicated that calculation of the theoretical concentration of 2,4-D applied in a lake epilimnion, assuming simple dilution and complete dispersion of

the herbicide, provides a rough estimate of the size of treatment which will produce detectable concentrations in most of the water column. For example, in Wood Lake where 18.5 ha were treated in 1980, the predicted concentration of 2,4-D in the epilimnion, assuming complete dilution and dispersion, was 0.0075 mg/L. The observed concentrations in water samples averaged 0.0058 mg/L for 19-30 days after treatments.

In a laboratory experiment, Lim (1978) investigated the persistence of 2,4-D acid residues in an acrylic cylinder "treated" at the rate of 22 kg a.i./ha. Herbicide concentrations in water reached a maximum level of 0.32 mg/L and detectable residues (greater than 0.001 mg/L) persisted for approximately four months. Absence of adapted microorganisms, comparatively small plant biomass, and no opportunity for dilution account for the relatively long period of detectable residues in the laboratory cylinder, although the herbicide residues eventually declined below detectable levels. Similar experiments by other investigators indicate 2,4-D acid can be degraded or complexed in the absence of dispersal, drift and dilution.

Following several experimental treatments, the concentrations of BEE and acid forms of 2,4-D were analysed separately in water samples. The rate of hydrolysis of the initial BEE form to acid form of 2,4-D is primarily a function of water temperature and pH (Zepp et al., 1975). Under conditions of high alkalinity and high temperature, hydrolysis proceeds more rapidly. Using pH values of 8.2-8.5 and temperatures of 15-20°C, Bothwell and Daley (1981) calculated the theoretical half-life of 2,4-D BEE to be 5-16 hours. Monitoring at Wood and Kalamalka Lake treatment sites in 1980 indicated that 2,4-D BEE was rapidly converted to the 2,4-D acid and was barely detectable in water samples 48 hours after application (Rudolph and Dyer, 1980).

The 2,4-D acid breaks down to an intermediate product, 2,4-dichlorophenol (DCP). This intermediate product is considered less stable than 2,4-D acid and detectable concentrations existed in samples taken no later than 24 hours after applications in the 1980 Kalamalka and Wood Lakes treatments.

It would appear that persistence of 2,4-D BEE and DCP residues are minimal under pH and temperature ranges similar to those of Okanagan Valley lakes during summer months. In conditions of low water temperature and/or low pH, these compounds can be expected to persist for longer periods.

4.5 HERBICIDE DRIFT

Herbicide drift must be considered where environmentally sensitive areas are being treated or where there may be conflicts with various water users in the treatment vicinity. In theory, the potential drift distance increases with the quantity of herbicide used. However, the actual drift distances appear to depend largely upon exposure of the treatment site to water movement. In lakes, currents are generated principally by prevailing winds.

Observations on herbicide drift from treatment areas were made by Water Management Branch staff following 21 applications during 1976-1981. Data are summarized in Table 2.

Little herbicide drift was observed outside treated areas of less than 1.0 ha. No 2,4-D acid was detected at concentrations over 0.01 mg/L in water samples taken at distances greater than 70 m from spot treatments. Concentrations around the detection limit (0.001 mg/L) were measured at a maximum distance of 460 m from treatments smaller than 1 ha, but usually were not detected over 100 m away.

Drift samples from small and large (up to 12 ha) treatments did not contain concentrations greater than 0.1 mg/L, with one exception. One sample, taken at a distance of 123 m from the 5.3 ha Kelowna foreshore treatment (1979), contained a concentration of 0.131 mg/L. In the many hundreds of other drift samples taken adjacent to large and small treatments, 2,4-D concentrations remained below 0.1 mg/L.

TABLE 2

DRIFT OF 2,4-D ACID FROM HERBICIDE TREATMENTS, 1976-1981

(DRIFT ESTIMATED FROM ANALYSES OF WATER SAMPLES COLLECTED IN SAMPLE GRID IN DIRECTION OF ANTICIPATED WATER MOVEMENT FROM TREATMENT AREAS)

A. Treatments smaller than 1 ha in open water, listed by treatment date

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Stations & (No. Samples)	Drift at Conc. >0.05 mg/L Max. Distance (m)	Drift at Conc. >0.05 mg/L Days[2] >50 m	Drift at Conc. >0.01 mg/L Max. Distance (m)	Drift at Conc. >0.01 mg/L Days[2] >50 m	Drift at Conc. >0.001 mg/L Max. Distance (m)	Drift at Conc. >0.001 mg/L Days[2] >50 m	Comments
N. Arm Okanagan Lake	31/5/76	0.60	22	7 (29)	ND	-	25 m	-	25 m	-	Stations 10-25 m from site[3]; treatments 50 m apart
	31/5/76	0.60	22	8 (38)	ND	-	30 m	-	90 m	3-8	Stations 25-150 m from site; treatments 50 m apart
N. Arm Okanagan Lake	12/7/77	0.67	22	6 (94)	ND	-	67 m	3	67 m	3	Stations 15-88 m from site[3]
	12/7/77	0.36	22/45	7 (70)	ND	-	15	-	15	-	Stations 15-64 m from site[3]; detected last on day 2
	12/7/77	0.30	33	5 (50)	27	-	27	-	27	-	Stations 15-46 m from site[3]; detected last on day 2
Lisheen Estates Kalamalka Lake	17/7/78	0.07	22	15 (90)	ND	-	ND	-	ND	-	Stations 80-360 m from site
Wilson's Landing Okanagan Lake	01/8/78	0.10	45	21 (160)	ND	-	ND	-	ND	-	Stations 60-400 m from sites
Cosens Bay, Kalamalka Lake	26/6/80	0.50 (6 sites)	45	2 (23)	ND	-	ND	-	460	20	Stations at 90 and 460 m from sites[3]
Coldstream Ck. Kalamalka Lake	09/9/80	1.0 (2 sites)	45	4 (72)	ND	-	ND	-	425	2	Stations 190, 425 and 610 m from sites[3]
Lisheen Estates Kalamalka Lake	30/7/80	0.2 (4 sites)	45	5 (64)	ND	-	ND	-	100	7	Stations 100-600 m from sites
S. End Kalamalka Lake	25/9/80	1.52 (6 sites)	45	6 (45)	ND	-	ND	-	1100	4-7	Stations 1100-2100 m from sites; suspect drift through Oyama Canal from 8.5 ha treatment at N. end Wood Lake on 27/9/80

TABLE 2 (Continued)

B. Treatments larger than 1 ha in open water, listed by treatment size.

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Stations & (Sample No.)	Drift at Conc. >0.05 mg/L Max. Distance (m)	Drift at Conc. >0.05 mg/L Days[2] >500 m	Drift at Conc. >0.01 mg/L Max. Distance (m)	Drift at Conc. >0.01 mg/L Days[2] >1000 m	Drift at Conc. >0.01 mg/L Days[2] >500 m	Drift at Conc. >0.001 mg/L Max. Distance(m)	Drift at Conc. >0.001 mg/L Days[2] >1000 m	Drift at Conc. >0.001 mg/L Days[2] >500 m	Comments
N. Arm Okanagan Lake	18/9/78	2.0	45	29 (409)	ND	-	40	-	-	400[b]	-	-	Stations 30-2500 m from site; last detected at 400 m 17 days after treatment
N. End Skaha Lake	23/6/77	2.4	22/45	5 (40)	ND	-	140	-	-	140	-	-	Stations 10-140 m from site[3]; 2,4-D was detected in only one drift station sample taken at 140 m with 0.017 mg/L on day 1
Naswhito Ck., Okanagan Lake	27/6/77	3.1	45	6 (72)	ND		40	-	-	40	-	-	Stations 10-180 m from site; 2,4-D detected in drift for 3 days only
Summerland, Okanagan Lake	14/8/78	4.0	45	37 (593)	1500	<1	1500	<1	<1	1500	2	11	Stations 200-3500 m from site; max. conc. at 1500 m = 0.067 mg/L; stations beyond 1500 m added after day 1[3]
Kelowna, Okanagan Lake	22/6/78	5.3	45	55 (799)	400	-	830	-	3	1450	4	4	Stations 60-5850 m from site; max conc. at 400 m = 0.063 mg/L
S. End Wood Lake	08/6/79	5.9	22/45	15 (78)	ND	-	2000	3	3	2000	3	3	Stations 500-7300 m from site; stations beyond 2000 m added after day 4[3]
N. End Kalamalka Lake	14/6/79	11.5	22/45	9 (108)	ND	-	1000	1	NS	1000	2	NS	Stations 1000-4200 m from site

TABLE 2 (Continued)

C. Treatments in areas where dispersion restricted by lake size

Location	Application Date	Treatment Size (ha)[1]	Treatment Rate (kg a.i./ha)	No. Sampling Station & (No. Samples)	Drift at Conc. >0.05 mg/L		Drift at Conc. >0.01 mg/L			Drift at Conc. >0.001 mg/L			Comments
					Max. Distance (m)	Days[2] >500 m	Max. Distance (m)	Days[2] >1000 m	Days[2] >500 m	Max. Distance (m)	Days[2] >1000 m	Days[2] >500 m	
S. End Wood Lake	10/9/80	10.0	45	23 (142)	ND	-	ND	-	-	6000	>14	>14	Stations 500-6000 m from sites[5]; most of the 930 ha lake epilimnion had 2,4-D conc. of 0.001-0.003 mg/L just before 8.5 ha treatment at north end on 27/9/80 which increased epilimnion conc. at all drift stations to max. of 0.0095 mg/L until lake turnover about 28/10/80
N. End Wood Lake	27/9/80	8.5	45	5 (86)	ND	-	ND	-	-	6000	30-33	30-33	
Champion Lake	11/9/81	0.56 (4 sites)	45	2 (20)	ND	-	470 m	-	-	470	-		Stations about 270 and 470 m from major treatment sites; much of the 14.6 ha lake surface had conc. of about 0.017 mg/L 20 days after treatment. No samples were taken after day 45 until 21/6/82, when no herbicide was detected (>0.001 mg/L)

Note: Herbicide residue samples taken closer than 10 m to treatment site not considered

ND = not detected; NS = not sampled

[1] Where several sites were treated, total area of all sites combined is given.

[2] Persistence is given as the last day when herbicide concentrations in water samples were greater than specified concentrations. All samples taken on the next day were below the specified concentrations. Persistence is shown as a range where time between sample dates >1 day.

[3] At these treatment sites, an increase in the size of the sample station grid within <1 day to 2 days after treatment may have resulted in detection of herbicide further than the maximum recorded.

[4] A sample with 2,4-D conc. of 0.003 mg/L collected on day 3, 2500 m from North Arm Okanagan Lake treatment site 18/9/78, was anomalous.

[5] Drift stations were located along entire length of Wood Lake (6000 m) for treatments on 10/9/80 and 27/9/80

In treatments greater than 4 ha in size, concentrations of 2,4-D acid over 0.01 mg/L were detected 830-2,000 m from the treated area, but within four days of treatment, concentrations had declined to less than 0.01 mg/L at these distances. Thus, drift of the herbicide at concentrations over 0.01 mg/L was shortlived. The drift distance reached by concentrations at the limit of detection (0.001 mg/L) was 1450-2000 m after these large treatments. Such drift occurred within a few days of these treatments and no herbicide was found in samples taken 1000 m or more beyond the treatment sites after five days.

Using the data in Table 2, the best estimate of maximum drift distances from 1-3 ha treatments is 500-1000 m for concentrations over 0.01 mg/L, but less than 0.1 mg/L. For treatments 3-5 ha in size, maximum drift distance is estimated to be 2000-2500 m for these concentrations. Drift distances anticipated from treatments over 5 ha in size cannot be well defined. Treatment of a 12 ha block in relatively calm, sheltered conditions produced drift of 0.01 mg/L no further than 1000-2500 m, but it is anticipated that greater drift could occur for short periods (i.e. 1-3 days) along shorelines exposed to wind-induced current. Therefore, predictions of drift distance for treatments over 5 ha should be made on a site specific basis.

In cases where treatments are sufficiently large that the herbicide is dispersed at detectable concentrations throughout an entire lake, the drift persistence is likely to be roughly the same as the persistence of herbicide in the treatment area. For example, herbicide drift was recorded throughout the entire epilimnion (warm surface water) of Wood Lake (930 ha) for a period of 30-33 days, following the 10.0 ha and 8.5 ha herbicide treatments in 1980.

The 1980 Wood Lake treatment data demonstrated that thermal stratification (developed during the summer months) strongly influenced the vertical distribution of herbicide drift residues in the lake. During summer in temperate climate lakes, the warm surface waters (epilimnion) typically are separated from the colder, deeper water (hypolimnion) by a steep temperature

gradient known as the thermocline. In Okanagan Valley mainstem lakes the thermocline typically becomes well established in summer and appears to resist any change until fall. Temperature profiles from Wood and Kalamalka Lakes indicated that the thermocline occurred at depths of 10 and 12 metres. Water samples taken after the large Wood Lake treatments in September, 1980 (Rudolph and Dyer, 1981) indicated that much of the surface and epilimnion contained detectable 2,4-D residues, but no herbicide was detected in the hypolimnion. Similarly, water samples taken after the Kelowna foreshore treatment of 1978 contained no detectable 2,4-D in the hypolimnion below surface water which contained 2,4-D residues.

The data from Wood Lake and Kelowna foreshore,Okanagan Lake, are consistent with established concepts of lake dynamics and give a strong indication that drifting herbicide from a surface application is extremely unlikely to penetrate a well-developed thermocline. In practical terms, this means that deep water intakes which draw water from below the thermocline are naturally protected from contamination during summer herbicide treatments. Therefore, it may be unnecessary to close deep water intakes when a summer herbicide treatment is carried out nearby.

Water samples collected by the Water Management Branch staff are considered subsurface bulk water samples. In a 1979 study of herbicide treatments in Wood and Kalamalka Lakes, Bothwell and Daley (1981) investigated the presence and transport of 2,4-D residues in the lake surface microlayer, an extremely thin layer at the air-water interface. Low concentrations of herbicide in the microlayer (<0.001 mg/L) travelled considerable distances in a short period of time. For example, in Wood Lake 2,4-D BEE residues travelled at least 2000 metres in 24 hours. However, in terms of the total amount of herbicide movement away from treatment sites, herbicide drift in the surface microlayer was considered to be insignificant (Bothwell and Daley, 1981).

4.6 HERBICIDE PERSISTENCE IN SEDIMENTS AND MOVEMENT IN GROUNDWATER

As root mortality is the primary objective of herbicide applications, residue accumulation in the bottom sediment is considered to be critical to herbicide uptake.

2,4-D acid was found in sediment samples only in the treated areas where Aqua-Kleen pellets landed. Herbicide concentrations in the sediment were highly variable between sampling locations and dates. Maximum concentrations of 2,4-D acid in the sediment generally were recorded within 11 days of treatments and ranged between 5.33 and 288.0 ppm, although mean concentrations were considerably lower. The high variability of sample concentrations within treatment areas was thought to be due to the small area sampled by the sediment corer, the granular nature of the herbicide pellets, and their uneven dispersion.

Because herbicide concentrations in the water column of open water treatment sites were usually below critical levels to kill Eurasian water milfoil, the higher concentrations in sediment were considered more important for effective treatment. This theory is further supported by the banding effect observed one year after some treatments. The bands appeared on aerial photographs as linear areas of treated Eurasian water milfoil showing signs of regrowth alternating with linear areas with hardly any vegetation. The bands corresponded with probable differences in herbicide granule densities on the bottom which may have resulted from uneven distribution of the herbicide in successive swath passes of the application boat.

Herbicide persistence in sediments ranged from approximately 1 to 11 months. Greater persistence was associated with the larger treatments and higher rates of application.

In a comparative study based upon the 1979 Wood and Kalamalka Lakes treatments, Bothwell and Daley (1981) demonstrated that 2,4-D BEE was hydro-

lyzed more slowly in the sediment than in the water column. However, Bothwell and Daley concluded that residues of 2,4-D acid, 2,4-D BEE, and 2,4-dichlorophenol from Aqua-Kleen did not persist at detectable levels for more than a few months. This confirms the conclusions of many other researchers on the degradation of 2,4-D in aquatic environments (Aly and Faust, 1964; Daley, 1971; Schultz and Harmon, 1974).

In a study conducted by Water Management Branch staff, the mobility of 2,4-D and water movement in Wood Lake sediment were investigated after the 1980 herbicide treatments. Of eight sediment samples collected 50 days after treatment, five had detectable 2,4-D acid residues, and four of these had significant residues in the pore water (interstitial water); no residues were found remaining in the sediment after removal of the pore water in most samples. The analyses suggest that little 2,4-D was bound to the sediment; the detectable 2,4-D was in the interstitial water (Kangasniemi and Nagpal, 1982).

The field sampling indicated that sediment 2,4-D is mainly dissolved in the pore water and should be considered mobile. Kangasniemi and Nagpal's conclusion is supported by the work of various authors who demonstrated that as an anion, 2,4-D is not readily absorbed by negatively charged soil particle surfaces.

In a complementary laboratory experiment utilizing a column of Wood Lake sediment, results indicated that the flow velocity of a 2,4-D slug travelled at about the same velocity as the interstitial water, suggesting that 2,4-D was not significantly adsorbed by the sediment.

In view of the potential mobility of 2,4-D in the sediment, concern has been raised about the possibility of 2,4-D contamination of ground waters feeding a domestic or irrigation water source such as a well or sandpoint. Preliminary data from a survey of the direction and velocity of water movement between the Wood Lake sediment-water interface indicated that groundwater flowed into the lake and 2,4-D contamination of adjacent wells could

not occur. However, in other lakes, the possibility exists that groundwater could flow from the lake to recharge adjacent wells. This is most likely to occur in areas downslope of lakes, such as at the outlet. Also, lake water may enter groundwater where the water table is depressed below the lake level due to the continuous pumping of a well.

Theoretically, 2,4-D could affect groundwater several kilometers away from a lake treatment. No general buffer zones should be applied to all situations. Each treatment area and any adjacent wells should be assessed on a site specific basis to determine if:

1) a hydraulic gradient exists which will move groundwater from a treatment area towards an active well;
2) there is hydraulic continuity;
3) the flow velocity is adequate to move the residues to wells before degradation occurs and
4) dilution is not sufficient to reduce 2,4-D concentrations below water quality objectives.

If these conditions exist, well use should be discontinued while residues persist above objective concentrations, taking into consideration the period of time it would take for groundwater to travel from the treated lake bottom to the well.

Groundwater movement may also play a role in reducing the effectiveness of 2,4-D applications by rapidly diluting herbicide concentrations in the sediment. If there was sufficient groundwater movement from the water table to the lake (i.e., upwelling), residues may be flushed from the sediment.

Following treatments in exposed locations, it is possible that 2,4-D in the sediment could be re-released back into the water column sometime after lake water residues become non-detectable (i.e. disturbance of sediment by wave action in large treatment areas near intakes). Concentrations of such herbicide in the water column were observed to be low. After the 1978 2,4-D

treatment of 5.3 ha along the Kelowna foreshore, the herbicide was detectable for only five days in the treatment area, then was non-detectable when sampled on days 6 and 8. However, concentrations of 0.001 to 0.007 mg/L were detected in bottom water samples on day 10, probably as a result of wind on the previous day. This recurrence of the herbicide in the treatment area water column was followed by measurement of detectable levels of 0.002 - 0.004 mg/L at drift stations up to 200 m from the treatment boundary on day 10 and 14 after five days of non-detection.

In the 1981 Solana Bay treatment, the presence of a hydraulic head between the treated bay and the untreated lake caused 2,4-D movement through the sand/clay barrier which separated Solana Bay from Osoyoos Lake. 2,4-D residues that moved through the barrier material were periodically detectable (0.003-0.03 mg/L) in the water column of Osoyoos Lake in the immediate vicinity of the barrier.

4.7 ALTERNATE WATER SUPPLY AND BUFFER ZONES

Water use surveys of the area likely to be affected by 2,4-D drift must be conducted prior to considering and establishing buffer zones around the area of herbicide application. The most recent water use license information should be obtained from Water Management Branch. Door to door surveys may be required to ensure both licensed and unlicensed lake and well water use are identified and mapped.

Buffer zone size around the proposed treatment area should be determined, based on the predicted drift of the herbicide and the maximum acceptable concentrations for the particular water use in the zone of herbicide influence. Where these water quality standards might be exceeded, water use should be discontinued after herbicide application until sufficient time has passed, or until monitoring indicates that residue levels are no longer a concern. Maximum acceptable levels of herbicide in water for various use purposes should be determined after consultation with local experts. Health

and Welfare Canada (1978) list the maximum acceptable concentration of 2,4-D in domestic supply as 0.1 mg/L although desirable levels are less than 0.001 mg/L.

Table 3 lists recommended buffer zone distances between treatments and lake water use, for various water quality objectives, based on the observed drift of the herbicide in B.C. lakes with similar pH and temperature ranges observed in Okanagan Valley mainstem lakes. A general zone between lakeshores and wells, where water use should be discontinued after herbicide treatments, cannot be specified. The source of well water and hydraulic gradients should be assessed where wells adjoin a proposed treatment area and buffer zones should be established accordingly.

The buffer zone distances in Table 3 are estimates of the maximum drift that would be anticipated under typical treatment conditions in large B.C. lake systems. The most information is available on small treatments; only 7 treatments over 1 ha in size (2-12 ha) were monitored for drift. A considerable distance was incorporated in the buffer zones to allow for uncertainty, particularly where limited data were available. The buffer zone distances apply in the direction of possible water movement and could be reduced in directions where it can be shown that little movement is possible. The time during which the buffer zones should be maintained might be reduced if monitoring indicates a more rapid dispersion of herbicide than indicated in Table 3 (which is likely following most treatments). Buffer zones might have to be increased under unusual conditions such as rapid movement of treated water in a confined channel.

TABLE 3

SUGGESTED BUFFER ZONES AND WATER USE CLOSURE PERIODS FOR 2,4-D TREATMENTS OF EURASIAN WATER MILFOIL IN BRITISH COLUMBIA

Open Lake Treatments[1]

	Water Quality Objective		
Treatment Size	0.1 mg/L 2,4-D	0.01 mg/L 2,4-D	0.001 mg/L 2,4-D
<1 ha	100 m (~6 days)	300 m (~20 days)	600 m (~20 days)
1 - 3 ha	200 m (~6 days)	1500 m for 4 days then 500 m (~30 days)	2000 m for 5 days then 800 m (~50 days)
3 - 5 ha	300 m (~6 days)	2500 m for 4 days then 1000 m (~40 days)	3500 m for 5 days then 1000 m (~50 days)

Enclosed Lake/Pond Treatments[2]

Water Quality Objective		
0.1 mg/L 2,4-D	0.01 mg/L 2,4-D	0.001 mg/L 2,4-D
~ 100 days	>190 days	>190 days

[1] Closure period in days is the longest time period that herbicide concentrations would remain above water quality objectives in most situations. Monitoring should verify that shorter closure periods are required in most sites.

[2] Closure periods listed are for water bodies where entire surface area was treated and would be shorter for sites where only a portion of the water body is treated. Buffer zones would be the entire lake or pond where complete dispersion of the herbicide results in a concentration greater than the water quality objective throughout the water body surface waters. Buffer zones would be smaller where dilution reduced 2,4-D concentrations below water quality objectives. Monitoring may be required to determine closure period.

The provision of alternate water to those users who must discontinue water use within buffer zones and treatment areas may increase the cost of herbicide treatments to such an extent that this aquatic weed control method is no longer cost effective. A preliminary study of alternate water requirements and costs should be made to determine the feasibility of such treatments even before an application is made for a Pesticide Use Permit. In some cases, the timing of the proposed treatment may make it possible to avoid the need for extensive alternate supplies. Alternate water supplies can be provided in a number of ways, ranging from local residents supplying their own needs to municipal installation of new pipelines to neighboring utilities. These arrangements are site specific. Costs are influenced by the need for any or all of the following arrangements:

(a) installation of temporary supply tanks, maintenance of same, trucking water to refill tanks daily, purchase of water supplied and/or;

(b) installation of temporary pipeline connections to a neighbouring utility, rental of pipe used, wages for specialists to help in making connections, purchase of the water used, purchase of the equipment to make the required connections, road works or driveway disruptions in laying and removing the temporary pipeline.

In some circumstances, no water source may be available to meet the needs of a large volume consumer.

The costs for the alternate water system are usually proportional to the volume of water which must be supplied. During the trial herbicide treatments in 1976-1981, the costs associated with supply of water for single large treatments (over 3 ha) ranged from under $10,000 to a maximum of approximately $47,000.

4.8 EFFECTS OF 2,4-D APPLICATION ON WATER QUALITY

Investigation of the use of 2,4-D for Eurasian water milfoil control in 1977 and 1978 included sampling for nineteen chemical and three physical water quality parameters at four open water sites and one enclosed site. Effects that have been observed following use of other herbicides include reduction in oxygen content of the water and increased phosphorous, nitrogen, and carbon concentrations. Results from the 1977 and 1978 investigations did not show any changes in water quality which could be attributed to 2,4-D treatments, even in enclosed water bodies where most of the area was treated and where there was considerable plant biomass (Anon, 1980a). This is likely due to the relatively slow effect of 2,4-D on Eurasian water milfoil and the decomposition of the plants over a period of weeks.

4.9 EFFECTS ON NON-TARGET ORGANISMS

4.9.1 OTHER MACROPHYTES

Qualitative and quantitative observations to date have indicated non-target plants were not eliminated at the application rates used to control Eurasian water milfoil populations (Anon, 1980 c). After treatment, plant species diversity was never reduced and the cover of some non-target species usually increased. For example, studies of 1977 and 1978 treatments indicated that in some cases a species (Ceratophyllum demersum) was observed less frequently after treatment, but other species, particularly Elodea canadensis, Potamogeton crispus, and Potamogeton pectinatus were more abundant after treatment. In two areas these species grew to nuisance levels one year after treatment. The period of relief from nuisance growth by herbicide treatments might be shortened in some areas due to regrowth of herbicide tolerant native species.

Post-treatment observations have shown that some individuals of non-target species will exhibit s_ ptoms of 2,4-D contact such as epinasty and

discoloration, but these effects appear to be temporary and sublethal. For example, a dense bed of Nymphaea odorata (water lily) associated with a dense bed of Eurasian water milfoil in a confined bay, was included in the south Kalamalka Lake treatments of 1980. The lilies exhibited some degree of epinasty and color change but were reported to have returned to normal population levels by the following spring.

4.9.2 PELAGIC ORGANISMS

A study by the International Pacific Salmon Fisheries Commission indicated that the 96 hour LC50 of 2,4-D BEE was approximately 0.45 mg/L for sockeye salmon fingerlings, coho salmon fry and pink salmon fry (Martens et al., 1980). However, no mortality or distress was observed among sockeye fingerlings exposed to 200 mg/L 2,4-D acid for 168 hours.

Water samples were collected by Water Management Branch staff to observe the rate of hydrolysis of 2,4-D BEE following an application to 10 ha in Wood Lake in 1980. The concentrations of 2,4-D BEE in the water column samples of the treated area were variable, both vertically and horizontally, indicating a patchy herbicide distribution. The maximum level of 2,4-D BEE was 1.38 mg/L in a single sample taken near the bottom three hours after treatment. The mean surface water concentration 1-5 hours after treatment was 0.20 mg/L and mean bottom water concentration was 0.38 mg/L. Concentrations declined to mean levels of 0.012 mg/L at the surface and 0.016 mg/L at the bottom after 24 hours.

The data from Wood Lake and theoretical calculations of Bothwell and Daley (1981) suggest that fish mortality due to 2,4-D BEE in treated areas is not likely to be significant at the rate of hydrolysis predicted for Okanagan Valley lakes. At lower temperatures and pH, hydrolysis will be slower and 2,4-D BEE may persist longer in treatment areas. Such persistence may be a concern if treatments are proposed for significantly large areas frequented by valuable fish species.

In practice, there has been no evidence of fish kills resulting from any of the 2,4-D treatments during trials in the Okanagan Valley lakes from 1976 to 1981. The treatment in Westside Cays monitored by the B.C. Fish and Wildlife Branch was of particular significance. In this enclosed site where the entire surface area was treated, concentrations of 2,4-D acid remained at an average concentration of 0.536 mg/L for 10 days after treatment. Fish could not escape from the treatment area. No fish kill was observed following treatment and samples of those fish present (squawfish, shiners, largescale suckers, carp, longnose suckers, perch, sculpins and peamouth chub) did not contain detectable 2,4-D when collected 50 to 71 days after treatment (Robinson and Morley, 1980).

Additional studies were conducted by the B.C. Fish and Wildlife Branch in 1978 to evaluate the effect of 2,4-D treatments on fish (South and Robinson, 1982). The data suggest that some fish captured in or near treated areas might contain detectable levels of the herbicide. Three fish (mountain whitefish, largescale sucker, and peamouth chub), of 10 netted within the treated area three to four days after the 5.3 ha treatment on the Kelowna foreshore in 1978, had concentrations of 2,4-D between 0.10 and 0.72 ppm. Only the sucker contained 2,4-D in muscle tissue, the other fish had 2,4-D in gills, skin, liver and/or alimentary tracts. Whole fish samples of mixed fish species including redside shiners, peamouth chub, prickly sculpins, northern squawfish, and longnose and largescale suckers, netted from the treatment area prior to application and held in cages, contained 2,4-D levels as high as 1.48 ppm when collected about three weeks after herbicide application. Only the mountain whitefish is angled for consumption. Most gamefish remain in cold water below the thermocline in summer and as a result, will not contact any herbicide.

It is unlikely that fish containing 2,4-D as a result of weed treatments would be taken for human consumption, although fish in shallow lakes subject to large treatments (>1 ha) might contain low 2,4-D concentrations for short periods. There is no indication that consumption

of such fish would risk exceeding the maximum acceptable daily intake values for 2,4-D established by the World Health Organization.

The Fish and Wildlife Branch also studied waterfowl frequenting Eurasian water milfoil populations. Analyses of tissues from waterfowl in and around treatment areas showed detectable levels of 2,4-D. The data suggest that 2,4-D residues were being actively eliminated by the waterfowl. Acute effects on waterfowl are not considered likely since concentrations of 2,4-D found in food sources were not high enough to be considered lethal.

Zooplankton, which are important in the diet of some fish species, can be affected by herbicide applications through direct toxicity (Walker, 1961), or secondary effects such as habitat loss (Brooker and Edwards, 1975). Data collected by the Fish and Wildlife Branch at several treatment sites in 1977 indicated a reduction in zooplankton species diversity. They concluded that the probable long term effect of a large-scale reduction of Eurasian water milfoil would be a corresponding reduction in associated zooplankton populations through habitat loss. Limnetic species and littoral zooplankton species not associated with Eurasian water milfoil would probably be unaffected (Robinson and Morley, 1980).

4.9.3 BENTHIC ORGANISMS

Brooker and Edwards (1975) stated that the "status" of most benthic species does not change as a result of herbicide use, but they also reported studies in which benthic invertebrate density increased after treatment. Smith and Isom (1967) concluded from their studies involving granular 2,4-D BEE that benthic populations were not "depressed" by the herbicide. In a study involving the same herbicide, Pierce (1961) observed that in no benthic invertebrate samples did any one group show significant variation from the seasonal fluctuation exhibited by the control.

The study conducted by Robinson and Morley (1980) in three control areas and three treated areas (0.3-0.7 ha in size) in the North Arm of Okanagan Lake indicated that the predominant short-term effect of the treatments was a temporary increase in abundance and a decrease in the diversity of benthic invertebrates. Increased abundance may reflect opportunities for detritus feeders, while decreased diversity may have resulted from toxicity or loss of habitat.

Water Management Branch data indicate that 2,4-D levels in sediments were higher and persisted longer than in the water column. Sample concentrations were highly variable and indicated the herbicide had a somewhat uneven distribution in sediments. However, it appears that 2,4-D can persist long enough and at levels that would produce toxic effects to a variety of benthic organisms if they were exposed to these sediments. In studies by Water Management Branch and Fish and Wildlife Branch, clams appeared relatively tolerant and samples showed no evidence of mortality in treated areas. In theory, toxic effects could occur to various amphipods and insect larvae living in or on the sediments, as determined from bioassays. However, changes in benthic communities were short-lived following the small treatments (<1.0 ha) monitored in Okanagan Lake. In larger treatments, such changes in benthic populations might be a concern if the treated areas supported a significant food source for valued fish species.

4.10 ALTERNATE CONTROL METHODS

Since 1972, the Ministry of Environment has been researching, developing, and testing aquatic plant management technologies. In relation to work done with aquatic herbicides, comparatively more effort has been directed at the investigation of non chemical control methods. Those options shown to have the most practical applications and currently in use include diver dredging, rotavating, shallow water tillage, harvesting, bottom barriers, and water level drawdown. Information presented in Table 4 and

TABLE 4

ESTIMATED OPERATING COSTS AND TREATMENT RATES
FOR SELECTED EURASIAN WATER MILFOIL CONTROL METHODS

METHOD	OPERATING COST[1] (cost/hectare)	AVERAGE RATE[2] (hectares/day)	COMMENTS
1. 2,4-D (BEE)	$700/ha @ 10 ha/day to $2500/ha @ 1 ha/day (herbicide cost at 45 kg a.i. per ha = $200/ha; capital cost/applicator unit about $12 000)	30 ha/day	Treatment area limited to 1 ha requires the same preparation and monitoring effort as a 10 ha plot, therefore cost/ha is much larger for smaller treatments. These operating costs do not include supplying any alternate water, which can increase costs considerably. Allowance for minimal monitoring is included.
2. Hydraulic Dredge	$5,000/ha (capital cost/dredge unit about $100 000)	0.1-0.2 ha/day	Operating cost obtained from a 2.9 ha test conducted by Aquatic Studies Branch in 1975. Rate is dependent on sediment depth removed and obstacles
3. Diver-Dredge	$2,500/ha to $19,000/ha (capital cost/dredge unit about $12 000)	.20 ha/day extremely sparse .02 ha/day moderate .01 ha/day very dense	Treatment costs and rates are highly dependent on weed density.
4. Rotavator	$400/ha to $1,200/ha (capital cost/machine about $60 000)	0.2-0.5 ha/day	Cost and rate are dependent on the degree of difficulty in treating the site and the number of passes necessary to remove most of the plant material.
5. Shallow Water Tillage	$400/ha (capital cost/machine about $60 000)	0.7 ha/day	Cost may increase in soft substrate areas or where obstacles are present.
6. Harvester	$1,200/ha (capital cost/machine about $90 000)	0.4 ha/day	Rate includes shore disposal of spoils.
7. Bottom Barriers	Burlap-$12,100/ha Polyethylene-$13,000/ha Window Screen-$20,000/ha Aquascreen-$50,000/ha	.05 ha/day	Polyethylene, window screen, and Aquascreen may be reusable and their high cost could likely be amortized over several years.

Figures do not include rental or depreciation of capital costs of machinery, expenses incurred from transport/launching of machines, or administration costs. Costs in 1982 Canadian dollars.

The above rates apply to an 8 hour work day and include set-up time.

the following brief descriptions explain the limitations and cost of the various mechanical aquatic weed control techniques for comparison with 2,4-D.

The Herbicide 2,4-D: The granular form of 2,4-D (impregnated in clay granules) is applied from a back-pack spreader to small areas around wharves or by spin-spreader from a boat to larger areas up to 10 ha or more. Nuisance weeds can be eliminated for two or more years from some areas. Major limitations are conflicts with water use.

Hydraulic Dredge: Portable dredges which utilize hydraulic cutterheads or rotating augers to remove lake sediment can also effectively remove aquatic weeds (entire stem and root systems). However, major drawbacks have been encountered in tests of this method: the operation is not efficient in rocky or debris laden areas, large spoils disposal areas are necessary, dredge volume capacities are insufficient for large-scale treatments, and costs are generally prohibitive when compared to other weed control technologies.

Diver Operated Dredge: With this dredge, a diver directs a small section head to remove individual plant stems and roots. Therefore, a unit can work around obstacles on irregular bottoms and remove almost all plant material if underwater visibility permits. It is best used in very sparse populations in smaller water bodies where more time would be spent searching for the target species than actual removal. The divers will inevitably leave a small amount of plant or root material which will reinfest the treatment area. The period of effective control is generally two to three years depending on the amount of plant material left behind and the rate of fragment introduction to the treatment area. Diver dredging is labour intensive, entails some risk to the diver operators, and is slow. Understandably, operating costs per area dredged can be high and generally prohibit treatment of dense and/or large Eurasian water milfoil populations.

Rotavator: Rotavation is a root tillage and removal technique, directed from a floating platform, which can be applied to large Eurasian water milfoil populations. It may provide two years of relief from nuisance growth where used on relatively smooth, sandy bottoms with few obstacles. Specific advantages over other surface based machines include a good working depth range of 0.5 m - 4.5 m and year round operation capability (ice absent). Collection of floating fragments and root masses (a separate operation) is usually necessary if the equipment is operated in summer. Rotavating efficiency is limited by the narrow width of the tiller head and the difficulty in guidance (2-3 repetitive passes are usually required to obtain complete bottom coverage), especially in irregular lake bottom areas.

Shallow Water Tillage: Substrate tillage using amphibious tracked vehicles or tractors in shallow water during seasonal low water levels has been shown to be a relatively fast and inexpensive way to effectively control Eurasian water milfoil in shallow bathing beaches where there are few obstacles. Utilizing land based equipment during the winter or early spring to remove Eurasian water milfoil root crowns also reduces the opportunity for fragment spread. Limitations to this technique include minimal water depth capability (generally less than 1 m), interference from debris or other obstructions, and operating problems on soft substrates.

Harvester: Harvesting Eurasian water milfoil is one of the most rapid and least expensive mechanical treatment operations. It provides short-term relief from dense, nuisance populations by removal of the surface mat to a depth of 1.5 m to 2.5 m. Regrowth is usually rapid and more than one treatment may be necessary during each recreational season. Further limitations are that the large harvesters now used in British Columbia require a substantial capital investment and are expensive to maintain, they cannot operate effectively in less than 1 m of water, and the operating season is short, limited to the summer when plants are at or near the surface.

Bottom Barriers: In tests, various materials have been spread out and anchored on the lake bottom to control small, nuisance Eurasian water

milfoil colonies. Common burlap is the cheapest covering that has been used, though it will decompose in one to two years. Black polyethylene film has a longer life but must be weighted properly to prevent it from being lifted by its natural buoyancy or by gases forming underneath (perforations will prevent gas build-up). Negatively buoyant, open mesh materials are more expensive but may be more practical for small applications. The considerable capital costs commonly associated with weed clearing machines are avoided; however, the expense of bottom barrier materials and slow speed of application (S.C.U.B.A. diving may be required) still result in a high cost per unit area of bottom covered. In addition, periodic maintenance may be necessary to clean, re-secure, or replace the bottom barrier panels at some interval.

Drawdown: Lowering the level of a lake or pond to expose Eurasian water milfoil can be an effective control option provided that the plant material is dried and/or frozen for a sufficient duration (usually several weeks are required). The range of possible water level fluctuations will determine how much littoral area can be affected; in many lakes only a small proportion of the total plant populations can be exposed. Cost may be negligible so long as the hydrological characteristics of the particular waterbody will allow passive drawdown (e.g., a dam or adjustable drop structure at the outlet) and water use is not affected (e.g., domestic intakes). In small ponds where easy drainage is not possible, it may be practical to pump out all of the water.

In general, there are a large number of factors which should be considered before selecting the method most suitable to a specific treatment need. Often more than one method should be employed if the site conditions are of significant complexity. It is anticipated that continued testing of mechanical control methods will improve these technologies.

5. APPLICATION OF HERBICIDE

5.1 PREPARATION

Prior to treatment, the sizes and shapes of the weed beds are determined through interpretation of air photographs and use of an areagraph chart or planimeter. Since air photo distortion may lead to some inaccuracy in the total calculated area of the treatment site, it may be necessary to measure actual distances and angles in the field using prominent landmarks as reference points. The boundaries of the treatment area are then marked with floats which serve as navigational aids for the applicator boat operator.

Immediately prior to herbicide application, beach closure and herbicide use warning signs must be erected in accordance with the Herbicide Use Permit.

5.2 EQUIPMENT AND PROCEDURES

It is important that the Aqua-Kleen granules are spread evenly over the treatment site. If small patches are left untreated, limited effectiveness may occur, as reinfestation will occur quickly. In order to prevent this problem, the applicator must have a method of navigating straight parallel swaths. Two methods have been used by Water Management Branch staff: 1) lining up navigation buoys; and 2) an electronic guidance system. In the first method, considerable time is required to establish a grid of buoys in the treatment area, and these buoys are subject to disturbance by wind. These problems are avoided with the electronic system. A tolerable amount of swath overlap is useful to compensate for side-slipping or wavering off the swath-line center while traversing the treatment area. Consideration should be given to splitting the application rate in half. The area is treated at half the application rate while travelling in one direction, then treated with the remaining herbicide, applied perpendicular to the original direction.

Aqua-Kleen is a granular formulation which limits the types of applicating equipment that can be used. Treatment over water imposes special considerations such as the maneuverability and compatibility of the applicator equipment with the applicator boat.

The simplicity and relatively low capital cost of application equipment is a major advantage of this technology. For large scale treatments, granular herbicide boom applicators are available with swath widths up to 15 m or large volume spin spreaders with swath widths up to 12 m. If a large spin spreader is to be used, the applicator craft must be substantial enough to accomodate the applicating equipment, operators, and a sizeable cargo of Aqua-Kleen and still be stable, maneuverable, and safe. For small treatments, low volume electric spin spreaders can be used on a small boat or a back-pack spreader can be operated from a small but stable boat.

The Water Management Branch incorporated the use of both the large volume spin spreader on a large boat and the back-pack spreader. Large herbicide treatments were carried out using an agricultural motor driven spin spreader mounted on the stern of a six metre aluminum boat. The rate of herbicide application was controlled by adjustments on the spin spreader in conjunction with a pre-determined boat speed. Tests of the spin spreader adjustment were carried out by timing the discharge rate of known quantities of attaclay blanks (the clay carrier without the 2,4-D). Knowing the discharge rate, the treatment supervisor calculated the boat speed required to achieve the desired application rate. The boat speed was determined by a timed passage through a known distance and was related to the motor speed, shown by a tachometer. The spreader adjustment and boat speed was monitored constantly during herbicide application to ensure that the required application rate is achieved. A back-pack spreader was used mainly for very small areas, shallow water applications and around wharves where navigation of a large boat is difficult.

After herbicide treatment is completed, the bags and remaining herbicide is packaged and sent back to the storage area. The local pesticide control officer is notified and arrangements are made for disposal of used bags.

6. MONITORING CONSIDERATIONS

6.1 MONITORING OBJECTIVES

Monitoring herbicide drift and persistence may be required in order to ensure there is no use of water above acceptable water quality standards and/or to establish that there is no environmental hazard. Generally, monitoring will be required only if water use in the treatment area or buffer zone has been interrupted and if it is necessary to determine when normal use can resume. In some cases, it may be desirable to locate a sample grid at the edge of the buffer zone to provide warning if drift is greater than anticipated. Where there is the possibility of a significant hydraulic connection between lake water and well water, the herbicide persistence in well water should be monitored.

The number of water sampling stations, their location and depth, and frequency of sampling must be determined on a site specific basis. However, some general guidelines have been proposed. In enclosed treatment areas, where the entire water body is affected, two sampling stations, centrally located within the treatment area, should suffice. Frequency of sampling depends on how urgently any discontinued water use must resume. In open water treatments, a minimum of two treatment area sampling stations should be established; also, it may be desirable to establish drift sampling stations in the buffer zone to determine when the buffer zone can be reduced and by how much. If it is necessary to take samples in the treatment area just to determine when water use can be resumed, then these samples could be taken after the time periods for the various water quality objectives indicated in Section 4.7. It may be desirable to reduce water closure as much as possible. Samples could be taken a few days after treatments to predict the rate of herbicide decline and to identify when further samples will confirm water use can be resumed.

In large treatments where active water intakes are located below the thermocline within the buffer zone, temperature profiles may be desirable in order to monitor the breakdown of summer thermal stratification.

In all herbicide monitoring situations, it is recommended that two consecutive days of sample concentrations meet water quality objectives before water use is resumed.

When monitoring herbicide persistence in lake water over pH 7, it should generally suffice to analyse water samples for 2,4-D acid. At lower pH, it may be necessary to analyse for both 2,4-D acid and 2,4-D BEE.

6.2 MONITORING PROCEDURES

The depth at which water samples should be taken is related to the water depth at the station. At sampling stations with a water depth of less than 2.0 m , it is suggested that only one mid-column sample be taken. Stations with depths between 2.0 m and 6.0 m should be sampled near the surface (0.1 m below the surface), and at 1.0 above the bottom. At deeper sites (drift stations), samples should be taken near the surface (0.1 m below the surface) and about 1.0 m above the thermocline (usually about 10 m deep).

Surface water samples are taken by submerging clean, capped bottles a minimum of 10 cm, removing the cap to fill the bottle, and then replacing the cap before surfacing. A Van Dorn sampler can be used to take the deeper samples.

The samples are placed in labelled, 750 ml Boston Brown bottles. A piece of aluminum foil is placed over the top to provide a good seal, and to prevent absorption of the 2,4-D into the plastic cap. The filled bottles are immediately packed into a cooler equipped with ice packs. Samples are preserved by the addition of 2 ml of HCl (hydrochloric acid, 50 percent

reagent grade) where analysis for 2,4-D in the acid form is required. The samples must be kept out of the sunlight and kept cool to prevent herbicide degradation. The method of collecting samples used for monitoring chemically treated areas must be consistent from day to day in order to ensure accurate results. All sample bottles must be pre-labelled with site number, station number, sample location (i.e. top, mid, bottom of water column), location (i.e. lake, river, creek), and date.

In order to ensure that samples arrive within 24 hours at an analytical laboratory, the coolers should be shipped by courier service.

6.3 ARRANGEMENTS FOR LABORATORY ANALYSIS

An important part of the procedure of shipping samples to an analytical laboratory is the completion of a number of forms to allow proper handling and analysis of samples by lab personnel, and to ensure registration of the results in a data storage system.

A general chemistry requisition form should accompany each sample in order to specify the type of analysis required, and to ensure that a written "receipt" of the result and a complete description of sampling will be recorded.

It is recommended that the analytical lab be notified in advance of a pending monitoring project to be prepared for the subsequent sample load. Should a large sample load be anticipated, it may be necessary to make arrangements for additional laboratory staff.

To date, the Provincial Environmental Laboratory located in Vancouver, B.C., has provided all analytical services for the Water Management Branch 2,4-D monitoring projects. Approximate costs of these analyses can be provided by the Environmental Laboratory or the Water Management Branch.

7.0 SUMMARY

1. Evaluations of the effectiveness, persistence and drift of 2,4-D (Aqua-Kleen formulation) were summarized following 33 treatments to control Eurasian water milfoil in British Columbia lakes between 1976 and 1981. Legal considerations, procedures for application and monitoring, and technical information on use of 2,4-D and other aquatic plant control methods were reviewed to provide direction in making applications for herbicide use and to provide guidelines for effective herbicide treatments.

2. Herbicide Use Permits must be obtained from the Pesticide Control Branch for aquatic applications in any body of water unless it is man made, self-contained and on private land. Permit requests should provide information on the purpose of the treatment, specific location and size of the treatment, treatment rate, possible conflicts with other water uses including domestic use and wildlife habitat, and why other control methods are inappropriate. Permit requirements usually specify treatment location, timing and application rates, restrictions to water use in area (e.g., shutting down domestic intakes for specified period), monitoring needs and steps for notification of the public.

3. Evaluation of herbicide treatments indicated that, in certain locations, 2,4-D was effective in removing nuisance Eurasian water milfoil growth for up to three years. The best control was obtained in sheltered bays or lagoons where the whole surface area was treated; in such cases the low treatment rate (22 kg a.i./ha) was recommended. The higher rate (44 kg a.i./ha) was recommended for open lake treatments. Better effectiveness was achieved in open water sites if treatments were made before dense surfacing populations developed in summer, or if plants were harvested before herbicide application, to allow granules to settle to the bottom and release 2,4-D near the plant root systems. Treatment of plants on rocky bottoms in open lake sites resulted in relatively low mortality as 2,4-D persistence was relatively shortlived compared to softer substrates.

4. Maximum 2,4-D concentrations in water within the treatment area exceeded 0.1 mg/L in only 40 percent of the open water treatment sites monitored. These maximum concentrations were low compared to levels required to kill Eurasian water milfoil. It was concluded that concentrations in the water column were not as important as the higher concentrations measured in sediment to achieve the plant mortality observed following these treatments. In enclosed treatment sites, concentrations in the water column remained above 1 mg/L for 1-7 weeks, which is well above the critical level required to kill Eurasian water milfoil.

5. Generally, 2,4-D acid concentrations in water declined to less than 0.01 mg/L within 15 days and to less than 0.001 mg/L within 40 days following open water treatments. Persistence was considerably longer in some enclosed sites (>190 days).

6. Drift of herbicide from open water treatment areas depended on the treatment area size and exposure of the site to water movement. Little herbicide drift was observed outside treatment areas less than 1 ha in size. For treatments 3-5 ha in size, maximum drift distances were about 100 m for concentrations over 0.1 mg/L, and about 2,000 m for concentrations over 0.01 mg/L. Maximum drift distances occurred within four days of treatment and subsequently declined. Drift distances for treatments over 5 ha should be predicted on a site specific basis.

7. The capacity of a lake to disperse and dilute 2,4-D after treatment was estimated by calculating the theoretical concentration of 2,4-D (assuming simple dilution) for the quantities of 2,4-D applied in the volume of water in the lake epilimnion (approximately the top 10 m). If the herbicide was likely to be detected after complete dispersion, the water body was considered enclosed. 2,4-D drift could persist as long as 2,4-D within the treatment area water column of an enclosed water body (>190 days).

8. Drifting herbicide from an application in the shallow littoral zone is unlikely to move below a well developed thermocline. It may not be necessary to close deep water intakes when a summer herbicide treatment is carried out nearby.

9. Maximum concentrations of 2,4-D in the sediment generally were recorded within 11 days of treatment and ranged between 1.61 ppm and 288.0 ppm. High herbicide concentrations in sediments were critical to Eurasian water milfoil mortality in open water treatments where herbicide concentrations in water were below effective levels. Uniform granule application is required to achieve uniform plant mortality.

10. Movement of 2,4-D in groundwater from lake treatment sites to nearby wells is unlikely, but possible, depending on a number of site-specific conditions. Groundwater movement from the lake bottom into a lake water column may reduce 2,4-D effectiveness by rapidly diluting herbicide concentrations in sediments.

11. Buffer zone size and duration adjacent to proposed treatment areas should be determined by predicted drift of the herbicide and maximum acceptable concentrations for the particular water use in the zone of herbicide influence. Using the Canadian Drinking Water Standard (0.1 mg/L 2,4-D) as the maximum acceptable concentration, a buffer zone of 300 m (for six days) generally would be adequate around a 5 ha or smaller application in an open water site.

12. No changes in water quality (including oxygen, phosphorus, nitrogen and carbon concentrations) could be attributed to the 2,4-D treatments in Okanagan Valley lakes. 2,4-D is selective for Eurasian water milfoil and little effect was observed on other aquatic plants in treatment areas. No adverse impacts of 2,4-D treatments on fish, waterfowl or other wildlife were observed. Agencies responsible for aquatic resources should be contacted about new treatment sites.

13. Results of testing the herbicide 2,4-D indicate it is one tool among several for aquatic plant management in specific situations; its suitability depends on such factors as site-specific costs and potential effectiveness. The main advantage of 2,4-D over other control methods is that in some sites it can be applied relatively quickly over large areas, at low cost and can eliminate nuisance Eurasian water milfoil growth for two to three years. The major limitations of herbicide use may be conflicts with water use, and water supply and monitoring costs if alternate water must be supplied to lake water users until the herbicide has dissipated.

8. REFERENCES

Adams, R.W. and M.A. Wallis. In prep. Studies on Aquatic Macrophytes Part XXXVIII. Observations on the control of Myriophyllum spicatum in Kalamalka and Wood Lakes using 2,4-D butoxyethanol ester in 1979 and 1980. Water Management Branch Report. British Columbia Ministry of Environment.

Aly, O.M. and S.D. Faust. 1964. Studies on the fate of 2,4-D and ester derivatives in natural surface water. Journal of Agriculture and Food Chemistry, 12(6):541-546.

Anon. 1979. Studies on Aquatic Macrophytes. Part XVIII. Data report on Eurasian water milfoil treatments with 2,4-D in the Okanagan Valley, 1977-78. Water Investigations Branch Report No. 2803. British Columbia Ministry of Environment. 129 pp.

Anon. 1980. Studies on Aquatic Macrophytes. Part XIX. Eurasian water milfoil treatments with 2,4-D in the Okanagan Valley, 1977-78.

(a) Volume 1: Description of study area, treatment methods and herbicide residue persistence in the water column and water quality implications. Inventory and Engineering Branch Report No. 2913. British Columbia Ministry of Environment. 142 pp.

(b) Volume 2: Herbicide residue concentrations and persistence in biological tissues and hydrosoils. Inventory and Engineering Branch Report No. 2914. British Columbia Ministry of Environment. 72 pp.

(c) Volume 3: Herbicide application effects on Eurasian water milfoil. Inventory and Engineering Branch Report No. 2915. British Columbia Ministry of Environment. 69 pp.

Bothwell, M.L. and R.J. Daley. 1981. Selected observations on the persistence, and transport of residues from Aqua Kleen 20 (2,4-D) treatments in Wood and Kalamalka Lakes, B.C. Environment Canada Inland Waters Directorate, Pacific and Yukon Region, Vancouver, B.C. 62 pp.

Brooker, M.P. and R.W. Edwards. 1975. Aquatic Herbicides and control of water weeds. Weed Research. 9(1):1-15.

Ceska, O. 1977. Studies on Aquatic Macrophytes. Part XVII. Phytochemical differentiation of Myriophyllum taxa collected in British Columbia, B.C. Water Investigations Branch Report No. 2614. British Columbia Ministry of Environment. 33 pp.

Elliston, R.A. and K.K. Steward. 1972. The response of Eurasian water milfoil to various concentrations and exposure periods of 2,4-D. Hyacinth Control J. 10:38-40.

Harris, C.I. 1967. Movement of herbicides in soil. Weeds, 15:214-216.

Health and Welfare Canada. 1980. Guidelines for Canadian drinking water quality, 1978. Canadian Government Publishing Centre, Hull, Quebec. 79 pp.

Kangasniemi, B.J. and N. Nagpal. 1982. A study of the potential for groundwater contamination from the use of 2,4-D for aquatic weed control. Water Management Branch Report No. 3121, British Columbia Ministry of Environment. 29 pp.

Lim, P.G. 1978. Studies on Aquatic Macrophytes. Part XVI. A laboratory experiment with granular 2,4-D for control of Eurasian water milfoil, 1976-77. Water Investigations Branch Report No. 2726. British Columbia Ministry of Environment. 25 pp.

Lim, P.G. and K.R. Lozoway. 1977. Studies on Aquatic Macrophytes. Part X. A field experiment with granular 2,4-D for control of Eurasian water milfoil, 1976. Water Investigations Branch Report No. 2613. British Columbia Ministry of Environment. 105 pp.

Martens, D.W., R.W. Gordon and J.A. Servizi. 1980. Toxicity of butoxyethanol ester of 2,4-D to selected salmon and trout. International Pacific Salmon Fisheries Commission, Progress Report No. 40. 18 pp.

Miller, R.W. and S.D. Faust. 1971. Sorption from aqueous solutions by organic clays: I. 2,4-D by Bentone 24. pp. 121-134. In: R.F. Gould (ed.). 1972. Fate of organic Pesticides in the Aquatic Environment. American Chemical Society, Washington.

National Research Council of Canada (N.R.C.C.). 1978. Phenoxy herbicides and their effect on environmental quality. Publication No. 16075, National Research Council, Ottawa.

Pierce, M.E. 1961. A study of the effect of weed killer 2,4-D Aqua granular on six experimental plots of Long Island, Dutchess County, New York. Proc. N.E. Weed Conf. 15:539-544.

Robinson, M.C. and R.L. Morley. 1980. Eurasian water milfoil studies. Volume II. A monitoring study of the effects of 2,4-D on fish and waterfowl as applied in lakes of the Okanagan Valley, 1977. Inventory and Engineering Branch Report No. 2918. British Columbia Ministry of Environment. 35 pp.

Rudolph, J.R. and C.E.W. Dyer. 1981. Studies on Aquatic Macrophytes. Part XXXI. Control of Myriophyllum spicatum in Kalamalka and Wood Lakes using 2,4-D butoxyethanol ester in 1980: Data Report. Assessment and Planning Bulletin 4. British Columbia Ministry of Environment. 39 pp.

South, E.L. and M.C. Robinson. 1982. Eurasian water milfoil studies. Volume III. Monitoring the effects of 2,4-D on fish and waterfowl and the effect of Eurasian water milfoil on fish and waterfowl in the Okanagan Valley, 1978. Water Management Branch Report No. 3133, British Columbia Ministry of Environment. 51 pp.

Smith, G.E. and B.G. Isom. 1967. Investigations of effects of large-scale application of 2,4-D on aquatic fauna and water quality. Pesticides Monitoring J., 1(3):16-21.

Walker, C.R. 1961. Toxicological effects of several herbicides to bottom dwelling fish food organisms in Missouri ponds. Proc. Northcentral Weed Control Conf. 18:104-105.

Weber, J.B. 1972. Interaction of Organic Pesticides with particulate matter in aquatic and soil systems. In: R.F. Gould (ed.). 1972. Fate of Organic Pesticides in the aquatic environment. American Chemical Society, Washington.

Weidner, C.W. 1974. Degradation in groundwater and mobility of herbicides. Thesis. University of Nebraska. Department of Agronomy. 69 pp.

Westerdahl, H.E. and J.F. Hall. 1983. Threshold concentrations for control of Eurasian water milfoil and sago pondweed. J. Aquat. Plant Manage. 21:22-25.

Zepp, R.G., N.L. Wolf, J.A. Gordon and G.L. Baughman. 1975. Dynamics of 2,4-D esters in surface waters: hydrolysis, photolysis and vaporization. Environ. Sci. Technol. 9:1144-1150.

9. APPENDICES

APPENDIX I CANADIAN LABEL FOR AQUA-KLEEN FORMULATION OF 2,4-D

Note mistake underlined on lower left of label should read....a second application may be required.

Net Weight 58 **22.7 Kg**

AQUA-KLEEN

GRANULAR

A 2,4-D WEED KILLER
FOR CONTROLLING WATER WEEDS

RESTRICTED

GENERAL INFORMATION

AQUA-KLEEN Granular contains 20% by weight of 2,4-D, as the low-volatile butoxy ethanol ester. This has been formulated on special heat treated attaclay granules that resist rapid decomposition in water. AQUA-KLEEN Granular sinks quickly to lake or pond bottoms and releases the weed killing chemical in the critical root zone area.

A water-oxygen ratio must be maintained because decaying weeds can use up oxygen that fish breathe. The most efficient use of AQUA-KLEEN Granular is early in the season when weed growth is sparse. During this period, weed decomposition is slow enough to not disturb the water-oxygen ratio, if the entire water body is treated at one time.

If treatments must be applied later in the season when the weed mass is dense, spread granules in lanes, leaving buffer strips which can then be treated when vegetation in treated lanes has disintegrated. During the growing season, weeds decompose in a 2 to 3 week period following treatment.

Buffer lanes should be 50 to 100 feet wide. Treated lanes should be as wide as the buffer strips.

For use in public bodies of water AQUA-KLEEN should be applied by Federal, Provincial or local agency personnel trained in aquatic weed control or by licensed commercial applicators under contract to the above agencies. Refer to permit sections for additional information about private ponds and lakes.

PERMIT TO USE CHEMICALS IN WATER

Permits are required to control weeds by chemical means in public waters. If your lake or pond is private and completely land-locked (not connected at any time of the year to other bodes of water either by an actively flowing stream or by surface seepage) a permit may not be required. Contact your local Department of Environment, Agriculture and/or Water Resources for a permit.

DIRECTIONS — RESTRICTED USES

Notice to User: This control product is to be used only in accordance with the directions on this label. It is an offence under the Pest Control Products Act to use a control product under unsafe conditions.

Nature of Restriction This product may be used only in the manner authorized; contact local authorities regarding appropriate use permits that may be required.

This product is to be used only in the manner outlinded; contact local officials for the appropriate use permits which may be required.

When to Apply

For best results, spread AQUA-KLEEN Granular in the spring or early summer, during the time weeds start to grow. If desired, this timing can be checked by sampling the lake bottom in areas heavily infested with weeds the year before.

If treatments are delayed until weeds form a dense mat or reach the surface, the higher rate, 225 kg/ha, or two lower rates 110 Kg/ha treatments should be made. Make the second treatment when heavy regrowth occurs or if weeds move in from untreated areas.

Occasionally, a second application will be necessary if heavy regrowth occurs or weeds move in from untreated areas.

This product is most effective in lakes and ponds with relatively slow rates of water exchange. The product may not be effective if applied in fast moving water such as a river or the mouth of a creek.

How to Apply

For large areas, use a fertilizer spreader or mechanical seeder such as the Gerber or Gandy. Before spreading any chemical, calibrate your equipment and method of application to be sure of spreading the proper amount. When using boats and power equipment, you must maintain the proper combination of (1) boat speed, (2) rate of delivery from the spreader, and (3) width of swath covered by the granules.

Use the following formula to calibrate your spreader's delivery in Kilograms of AQUA-KLEEN Granular per minute.

$$\frac{\text{kilometers per hour} \times \text{spreader width (meters)} \times \text{kilograms per hectare}}{600} = \text{kilograms per minute}$$

For small areas — around docks or isolated patches of weeds — use a portable spreader such as the Cyclone seeder. Estimate or measure out the area you want to treat. Weigh out the amount of material needed and spread this uniformly over the area. More uniform coverage is obtained by dividing the required amount in two and covering the area twice, applying the second half at right angles to the first.

How to Apply

Spot treatments can be made for small local infestations or for purposes of retreating areas missed in the first application or preventing the establishment of weed fragments drifting in from untreated areas.

When spreading AQUA-KLEEN Granular from a boat, we suggest setting out guide posts at frequent intervals marking out the area. This helps to steer a straight course.

Amounts to Use

Rates of application vary with the resistance of weed species to the chemical, density of weed mass at time of treatment, water depth, and rate of water flow through the treated area. Use the higher rate for dense weeds, when water is more than 2.4 meters deep and where there is a large volume turnover.

	AQUA-KLEEN	
	Kilograms per Hectare	Kilograms per 100 sq. meters
SUSCEPTIBLE WEEDS		
Water milfoil (Myriophyllum spp.)	110—225	1.25—2.5
Water stargrass (Heteranthera dubia)	110	1.25
SLIGHTLY TO MODERATELY RESISTANT WEEDS	175—225	1.75—2.5

Bladderwort (Utricularia spp.) White water lily (Nymphaea spp.) Yellow water lily or spatterdock* (Nuphar spp.) Water shield (Brasenia spp.)
Marine eelgrass (Zostera marina) Coontail* (Ceratophyllum demersum)
*Repeat treatments may be needed

This product is designed to control the weeds listed on the label. Control of other weeds may not be satisfactory. Generally, weeds are difficult to control in lakes where water replacement comes from bottom springs.

Water pH

Lake water that is extremely acid or alkaline may influence the effectiveness of AQUA-KLEEN Granular. A pH on the acid side (pH 6.0 or below) generally favors the action of the chemical while a pH on the alkaline side (pH 8.0 or above) may reduce the action. If regrowth occurs within a period of 6 to 8 weeks, a second application may be required.

Eelgrass Control in Maritime Oyster Farms

AQUA-KLEEN effectively controls Marine eelgrass (Zostera marina) in Eastern Canadian Oyster farming areas. Application rates will kill weeds and thereby facilitate oyster harvesting. Make only one application per season.

Apply AQUA-KLEEN during the summer when eelgrass has begun to flower. For maximum weed control treat during warm weather when water exchange is at a minimum.

Treat at low slack tide to reduce dilution by water movement. In very shallow areas treat at high slack water.

Natural water movement will spread AQUA-KLEEN beyond the treated area. An additional perimeter around the actual treated area should be regarded as affected by AQUA-KLEEN.

Treat at least 60 days before the first oyster harvest. Avoid harvesting other shell fish, such as clams, from the treated area and perimeter during the same 60 day period.

NOTICE TO BUYER: Seller's guarantee shall be limited to the terms set out on the label and subject thereto, the buyer assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

PRECAUTION

Avoid contact with skin, eyes or clothing. Do not store near fertilizer, seeds, insecticides or fungicides. Do not use in a greenhouse. Clean spreader equipment thoroughly before using it for any other purpose.

CAUTION

Unless otherwise authorized by the agency issuing the governing use permit, do not treat within 1.0 kilometer of any active water intake.

POTABLE WATERS

Do not use water from the treated area for consumption by humans or livestock for at least 60 days after treatment in confined waters, or for at least 21 days after treatment in open bodies of water, unless analysis indicates that 2,4-D residues do not exceed that listed in the Canadian Drinking Water Standards and Objectives.

IRRIGATION

Do not use water from the treated area for the preparation of agricultural spray mixtures or for irrigation of 2,4-D sensitive crops for at least 60 days after treatment in confined waters or for at least 21 days after treatment in open bodies of water, unless an approved assay shows that the water is suitable for such purposes. Many crops such as tomatoes, legumes, cucurbits, grapes and cole crops are sensitive to 2,4-D.

Do not use this product for purposes other than those recommended on this label.

UNION CARBIDE
AGRICULTURAL PRODUCTS COMPANY, INC.
P.O. Box 1198
Chatham, Ontario N7M 5L8

Registration No. 9907 Pest Control Products Act
READ THE LABEL BEFORE USING

GUARANTEE
2,4-D equivalent ..... 20% by weight

APPENDIX II APPLICATION FORM FOR PESTICIDE USE PERMIT

Suggested information letter to accompany application for pesticide use permit for treatment of Eurasian water milfoil

Director,
Pesticide Control Branch,
Ministry of Environment,
810 Blanshard St.,
Victoria, B.C.
V8V 1X5

Dear Sir:

Re: Application for herbicide use permit

A permit is requested for herbicide application for the control of Eurasian water milfoil (Myriophyllum spicatum) as described below. Completed permit application forms and maps showing treatment sites are enclosed.

Herbicide: Aqua-Kleen 20 (2,4-D as active ingredient)

Site: (specified location in named lake)

Objective

- Nuisance caused by Eurasian water milfoil including size of area affected
- Objective in controlling nuisance weeds e.g.,
  - to protect recreational value of lakefront
  - to improve water use capabilities
  - to minimize spread
  - to prevent flooding
- Reason for selection of herbicide

Application Procedure

- Who will apply herbicide (licensed applicator)
- Equipment to be used
- Treatment rate
- Timing

Water Use Affected By Treatment

- Anticipated drift and persistence
- Water use (including domestic, irrigation, livestock, and wildlife habitat) in treatment area and area of anticipated drift

..2

Alternate Water Supplies

- What alternate water supplies will be provided to affected water users, if any

Public Safety

- Potential for public contact of treated water and precautions to prevent this, e.g., posting of signs on beaches

Monitoring Program

- Monitoring which will be done for herbicide residues to determine when they are no longer a concern to water users following treatment

Please contact (proponent or special advisor) for additional details regarding the proposed herbicide treatment procedures and monitoring program.

Yours truly,

Province of British Columbia
Ministry of Environment
Pesticide Control Branch
810 Blanshard Street
Victoria
British Columbia V8V 1X5
Phone: 387-4321

APPLICATION FOR A PESTICIDE CONTROL ACT PUBLIC LAND OR AQUATIC PESTICIDE USE PERMIT

Seven completed copies of this form and maps must be submitted to the Pesticide Control Branch at least four months prior to proposed project commencement date.

A

Applicant's Name: _____ Telephone No: _____

Address: _____ Pest Control Service Licence No: _____

Contractor: _____ Telephone No.: _____

Address: _____ Pest Control Service Licence No: _____

B

Proposed Dates of Pesticide Application: Commencement Date: e.g., August 15, 1983

Completion Date: e.g., September 30, 1983

C Details of Project:

Location: (a) Nearest Town: _____

(b) Specific: e.g., between specified headlands in specified lake

Purpose: (a) Control of Eurasian water milfoil

(b) Target Species: Eurasian water milfoil (Myriophyllum spicatum)

Treatment Area (hectares): e.g., 4 hectares

Land Ownership: Public (X) Private ( )

Please attach detailed map(s) of proposed treatment area.

D Information on Proposed Pesticide:

Trade Name: Aqua-Kleen 20 Pest Control Products Act Registration Number: 9907

Active Ingredient: 2,4-D butoxyethanol ester Carrier/Diluent: attaclay granules

Rate of Application (kg of a.i. per unit area or tree etc.): e.g., 45 Kg/ha

Formulation: 20% butoxyethanol ester granular

Total quantity of chemical to be used on project (expressed in kg of a.i.): 180 Kg

Is this an application for a permit to use a registered pesticide for a purpose other than prescribed on the pesticide label? Yes ( ) No (X)

/2

PAGE 2

Application for a Pesticide Control Act
Public Land or Aquatic Pesticide Use Permit

E Equipment:

Ground:	Truck mounted spray boom	( )		Handbroadcast	( )
	Backpack sprayer	( )		Hack & squirt	( )
	Mistblower with granular spray attachment	(X)		Cyclone spreader	( )
	Powerhose/Nozzle	( )	or	Other (specify) spin spreader	
Aerial:	Helicopter	( )		Fixed Wing	( )

F Method of Application:

Spot ( ) Broadcast (X) Other (specify) _____

G Aquatic Information:

Do you propose to apply pesticides within 30 metres of waterbodies (e.g. rivers, lakes, streams) or wells? Yes ( ) No ( )

If "Yes" are these waterbodies or wells used for domestic purposes? Yes ( ) No ( )

If "Yes" are these waterbodies or wells used for irrigation purposes? Yes ( ) No ( )

If "No" what is the estimated distance to the nearest water intake or well used for domestic or irrigation water purposes? _____

H Supervisor of Project:

Individual Responsible for Project: _____ Pesticide Applicator Certificate & Number: _____

Title: _____ Category: _____

Telephone Number: Home: _____ Office: _____

Signed: _____

Title: _____

Date: _____

Form: F-163
Rev. 10-81

POOR

QUALITY

ORIGINAL